A Systemic Study of Learners’ Knowledge Sharing and Collaborative Skills Development: A Case Study in a British Business School

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Abstract

Knowledge management, as Leistner (2010) argues, is a "misnomer". Knowledge cannot be managed since it relates to prior experience and is present merely in the mind of individuals (p. 4). We can manage knowledge flow, but not the knowledge itself. Leistner states that *''you can enable a flow by creating an environment that people find safe, attractive, and efficient, and that motivates them to share their knowledge. This could be either face-to-face or by recording relevant information that can be used by others to re-create knowledge in their own frame of reference''* (p. 10). Therefore, managing the flow is "as *much about creating conditions that will make sharing more likely as it is about trying to have a direct influence on people''* (pp. 17-18).

In the arena of creating such conditions, operational research (OR) is assumed to offer special capacities to lead the advancements in knowledge management and knowledge sharing research. However, the role of OR is not clear in knowledge management. There is also very little account of OR studies concerning knowledge management in combination with social network analysis. This situation has not changed over past years. In addition, although soft-OR tools promote specific solutions with which to tackle complexity management in organisations, there are very few studies concerning the use of action research and soft-OR tools such as the Viable System Model, which are designed specifically for knowledge sharing projects and simulating social networks.

This research intends to design, develop and implement a soft canonical operational research (SCOR) methodological framework for the processes of knowledge sharing. The researcher combines Davison et al.'s (2012) canonical action research and Checkland's (1985) F-M-A soft account of action research. The framework has, in itself, an embedded solution for skill development and performance improvement through collaborative knowledge sharing and experiential learning/practising. In this research, a combinative perspective of VSM and SNA is considered.

Adopting a pragmatic philosophy with an interpretivist ontology and relativist epistemology, the researcher inductively conducted two cycles of action research and analysed the outcomes. Four types of transformations occurred in (1) individuals' skill level, (2) performance, (3) knowledge network and (4) gradual development of strategies across levels. This research elucidates said transformations and explains the key mechanisms for facilitating collective knowledge sharing in order to develop skills and to improve performance. It also brings to light the evidence regarding two unplanned phenomena that occurred in both cycles: leadership development and autopoiesis.

Reflection is provided on the design of the soft-OR multi-methodology and on how this design has been useful and effective in the present research. In addition, the study's contributions to knowledge and practice are also explained. This research suggests that guided self-organisation is a more effective approach for skill development than traditional methods and that it can create an effective context in which a knowledge network is able to reproduce itself. Finally, the limitations of the research and implications for future studies are clarified.

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List of Abbreviations

OR	Operational Research
KM	Knowledge Management
SNA	Social Network Analysis
Soft-OR	Soft Operational Research
VSM	Viable System Model
F-M-A	Framework of theories-Methodology-Area of Application
HEI	Higher Education Institution
DEA	Data Envelopment Analysis
APS	Academic and Professional Skills
SCOR	Soft Canonical Operational Research
APS Module	APS project
OP1	Operational Plan 1
OP2	Operational Plan 2
OP3	Operational Plan 3 Note: OP3 also relates to Maths knowledge network as well as extra maths sessions.

Chapter 1: Introduction

1.0. Introduction

This research revolves around a management perspective on the design, development and implementation of a systemic multi-methodology for the "Process of Knowledge Sharing". It aims to provide a Soft Canonical Operational Research (SCOR) methodology framework for managing the complexities involved in the processes of knowledge sharing in a learning context. This multi-methodology strives to create an effective knowledge sharing approach, which promotes collaborative learning.

Starting with the concept of knowledge and considering the multi-disciplinary perspective of this research, the author follows the definition of knowledge that is offered by Davenport and Prusak (1998), specifically:

> *"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" (Davenport and Prusak, 1998, p.5).*

The width and breadth of knowledge as well as its process modes (including social agent's experiencing, reasoning and common sense making), all of which are rather approximate than exact, prove it to be fuzzy and complex (Zadeh, 1989). To deal with such complexities, it is necessary to avoid linear solutions and to use a holistic and systemic methodology for action research in knowledge sharing projects.

In this vein, a survey by Edwards et al. (2009) aims at establishing the contribution of operational research (OR) in knowledge management (KM) reveals that OR has no clear role in KM, though OR is assumed to have special capacities to lead the advancements in KM research. The same survey also emphasises that there is very little account of OR studies in relation to KM with SNA. In addition, even though soft-OR tools (soft operational research tools) advocate specific solutions for complexity management in organisations (Espinosa and Walker, 2013), the literature review of this thesis found very few studies which have used soft-OR tools to deal with the complexities of knowledge sharing projects. According to the literature reviewed for the present thesis, this situation has not improved over the past years.

It is true that SNA has been very attractive for those researching non-OR knowledge sharing. However, only 57 articles emerged from the literature search for studies regarding knowledge sharing which use "OR and SNA" or which use "soft-OR and SNA" on JORS, KMRP, Informs (including management science), ABI-Informed complete (business and management), Web of Science, Science Direct (including Omega) and Scopus. After detailed study, these 57 were reduced to 3 journal articles.

Furthermore, knowledge sharing is the most difficult process in KM because central to the process of knowledge sharing is dealing with the complexities of tacit and experiential knowledge as one of the knowledge varieties (Jones and Leonard, 2009, Omotayo, 2015). Since knowers are social agents and knowledge resides and originates in their minds (Davenport and Prusak, 1998; Sveiby, 2001), the very act of knowledge sharing occurs between and among them. In other words, knowledge is shared in a network of *n* social agents (n>1). It is for this very reason that literature of knowledge sharing is saturated of social network analysis (SNA). Blankenship and Ruona (2009) highlight that SNA has been used as a method for decades. They also mention the recent dramatic increase in using SNA to map the flow of knowledge within an organisation in order to better understand the process of knowledge sharing in informal networks and communities. Yet, the literature review of this thesis reveals a scarcity of studies on managing social networks using soft-OR and action research which is specifically designed for knowledge sharing projects.

Aiming to design, develop and implement a soft-OR solution to enhance the process of knowledge sharing and to recognise the complexities in such a process, the Viable System Model (VSM), as a well-known soft-OR tool for managing complexity, is considered. Particularly, VSM is a powerful tool for systems design as well as performance measurement (Espinosa and Walker, 2013). VSM is able to model how information and knowledge flow through communication channels (Flood and Jackson, 1991, p.92), highlighting both existing and missing communication patterns in the concerned channels (Nyström, 2006, p.523). In addition, such detailed analysis of relationships among the components of a system is not present in any of the other OR/soft-OR models (Preece and Shaw, 2013). VSM also supports the understanding of unbalances in the joint undertaking of specific tasks and offers criteria for redesigning tasks in more effective ways (Espinosa and Walker, 2013). It is underpinned by cybernetic science, i.e. the science of steering the system towards meeting objectives through study of information flow as well as control actions (Heylighen and Joslyn, 2001). These features therefore make VSM a superior choice among other OR/soft-OR complexity management methods and tools. However, searching databases for studies on the "process of knowledge sharing" through using "VSM and SNA" led to 0 articles.

Hence, the present thesis ventures to fill these gaps in the field and presents an exploratory soft canonical operational research project where the researcher, as a reflective practitioner (Schön, 1991), designs and facilitates processes of knowledge sharing in a non-hierarchical and collaborative fashion, leading to capability development and performance improvement for learners. The methodological framework of this interdisciplinary research benefits from a combination of Checkland's (1985) F-M-A account of action research from the soft systems perspective, and Davison et al.'s (2012) canonical action research (CAR) and its principles and criteria. The suggested multi-methodological framework incorporates VSM and SNA as the main instrumental and focal theories among others to design a soft-OR solution for the process of knowledge sharing. Viable system diagnosis and SNA are used for problem structuring. The collective of issues are then presented. In order to simulate the social network of knowledge, Nahapiet and Ghoshal's (1998) three dimensions of social capital theory are used. In addition, Achterbergh and Vriens' (2002) domains of viable knowledge are employed in the contextual knowledge sharing scenarios. This action research embeds distinctive features of VSM, such as self-organisation, within a knowledge network of learners.

1.1. Context of Research

The research context of this thesis relates to the delivery of educational services in a business school at a UK Higher Education Institution (HEI). The choice of this context is made for three reasons. First, a HEI is recognised as the natural context where knowledge and skills are generated, attained, shared and utilised. Second, there was a call for an innovative solution in the business school concerned, which could suit the research proposal of this thesis. Since the call was inviting suggestions for solutions related to skills development and performance improvement, it could match the criteria for a soft canonical operational research project focused on a knowledge sharing process and reliable data access could be ensured. Third, the researcher, as a system analyst, a reflective practitioner and a mathematician, had experience of successful complexity management for knowledge sharing processes, in terms of skills and capability development and performance improvement in similar contexts.

In the HEI environment, performance management (i.e. teaching-learning assessment) is complex, since both subjective and objective types of criteria are to be considered (Thanassoulis et al., 2017). In this vein, the quantity of education, i.e. the number of successfully-performing students, is very important. Yet, the quality of education (which is usually analysed by the level of students' performance), is even more critical (Johnes et al., 2017).

According to Witte and Lopex-Torres (2017), the hard-OR perspective of performance management perceives universities as knowledge production factories with inputs, processes and outputs. They argue that hard-OR researchers find that the way in which production technologies are defined/estimated is very complex (the production technologies that are used by students to gain knowledge). They state that researchers are widely using non-parametric techniques such as Data Envelopment Analysis (DEA) to assess educational efficiency in schools and universities. In this regard, Mayston (2017) argues that convexity (causal) assumptions about existing technology and possible knowledge production associated to that might not hold. This is the case when performance evaluation comprises measures for quality assessment. DEA in this scenario will therefore overestimate the scope of improvements in efficiency and underestimate the significance of improvements. The above author then calls for an alternative non-parametric allocative efficiency evaluation technique that is output-orientated.

While hard-OR tools are pushing rigorously to solve efficiency problems along with other issues such as scheduling and resourcing in educational domains (Johnes, 2017), a literature review by Pagano and Paucar-Caceres (2013) highlights that little account of research exists in the literature using systems thinking on education management or on management of learning. Hart and Paucar-Caceres (2017) use VSM to evaluate technology-supported learning, yet it can be argued that it is still very difficult to share the 'tacit' knowledge through online channels and in virtual spaces. Since the technology-supported type of learning is assisted by the use of technology, and participants did not have much chance to construct something in the real world (a building in this scenario) which could provide them with first-hand tacit (experiential) knowledge, the outcome of the learning process might not meet the level of expected performance (expectation of employers in the external environment). The authors themselves acknowledge this and state that their intention behind using the technology-assisted learning was to facilitate the process of learning in some way only.

Working on sharing tacit knowledge along with other knowledge varieties, this thesis provides a soft canonical OR multi-methodology to not only help the learners learn the underpinning concepts but also to enable them to share their knowledge, develop their skills and improve their own performance individually and collectively. Above that, they could learn *how to learn* through a bottom up approach. The latter aspect has been missed in management literature in general and educational literature in particular. The literature review of this thesis reveals the scarcity of studies that could manage the complexities of learning projects using soft-OR tools such as VSM.

Byrne (2014) states that there is an extensive body of literature which uses a complex frame of reference for education as well as for pedagogy. It can be argued that although complexity theory is closely related to systems thinking, such studies have used complexity theory as a way to explain educational and pedagogical phenomena. In this regard, Cochran-Smith et al. (2014) specify that complexity theory cannot provide causal explanations with implications for practice. Therefore, it cannot be used for action or operational research in the educational domain.

From the other side, Checkland (1994) emphasises that soft systems methodologies are pertinent in solving problems of modern management. He compares hard-systems and soft-systems models of organisation and stresses that hard-systems models are based on clear-cut assumptions regarding performance measures and defined hierarchies of communication and authority, with a detailed plan in order to reach organisational goals. In contrast, soft-systems models consider the realities of capacity increase through communication, greater goal complexity and weaker relationships between power and authority. These conditions influence learning and education in the HEI environment.

1.1.1. Research Problem

In order to formulate the research problem, there is a need to provide more background information. From the macro perspective of the context, since both the quantity and quality of educational performance in HEIs require a variety of resources, there are extra pressures on HEIs to be efficient in the provision of education. This is in fact because the current cuts in public finances have resulted in HEIs losing some of their public funds (Johnes et al., 2017). On the other hand, HEIs are part of the service industry and a major criterion for a HEI to gain competitive advantages is the university rankings (Douglas et al., 2006). High-ranked, middle-ranked and low-ranked universities seek different strategies to gain financial advantages. In low- and middle-ranked universities, this could be through an increase in admission of undergraduate students to retain the market share and to ensure the revenue via students' finances vs HEIs' financial cuts. It can be argued that this might be at the cost of lowering the admission criteria. Such students are entering higher education but are not reasonably skilled (especially in maths). In fact, the results of GCSEs in UK secondary education are not promising in terms of maths and English**.** The solutions offered to tackle the problems in secondary education have not yielded any progress in terms of maths performance. Chart 1 shows that approximately the same rate of failure (F, G, and U) is reoccurring every year (bstubbs.co.uk, 2015).

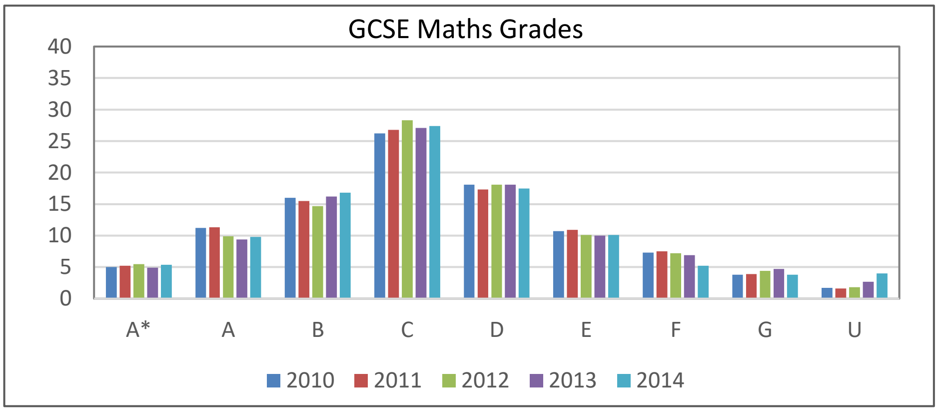


Chart 1: Secondary Education – GCSE Maths Performance in UK (Data: bstubbs.co.uk, 2015)

In addition, the university context/environment is very different from secondary education in terms of attendance, level of independence, motivation, support, class hours, type of assignments, class sizes, scheduling, grievance, as well as course fees which leave students confused and emotionally anxious. Universities therefore have to strategise critically in their degree programmes to tackle such issues (See Figure 1).

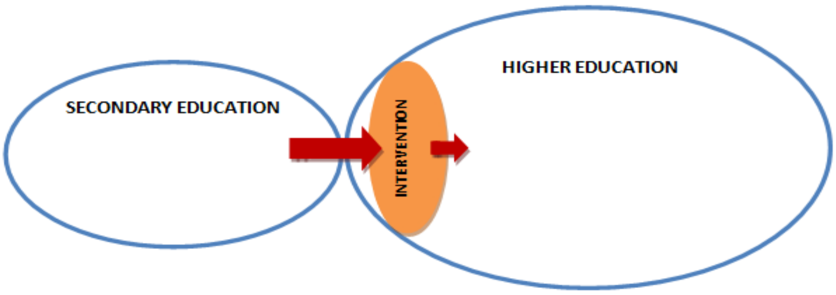


Figure 1: Strategic Situation in Low- and Middle-ranked universities for Skills Intervention

In the concerned business school of the middle-ranked HEI, lowering the admission criteria, the ranking in the league table, and other contextual factors (discussed in detail in Chapter 4), resulted in a situation where this HEI absorbed many more low-skilled students, i.e. more students with GCSE grades C, D, E, and F, than those with GSCE grades A and B. Hence, despite the fact that Chart 1 depicts a normal distribution in the UK as a whole, the students who attend a middle- or low-ranked HEI would not be a normal distributed population in terms of their GCSE grades. This suggests that the issue of lack of basic maths skills was being transferred to low- and-middle-ranked HEIs. Therefore, in the business school relevant to this research, the Academic and Professional Skills (APS) module was designed and developed as a result of such strategy and aimed to fully equip first-year undergraduate students with both qualitative and quantitative skills, and in particular quantitative (maths) skills. The students were required to take a strategic venture through the compulsory APS module. The module comprised two components, namely maths and writing skills. This dissertation initiates the formulation of the research problem from the context of a call for innovative solutions in a UK-based business school. The maths component of the APS is where the initially-identified problems of the call lay. The issues were discussed in the initial discussion with the module leader and she explained the situation and conditions involved in the APS module. According to the module leader, APS is a strategic and compulsory module for undergraduate students who embark on business and management courses and is regarded as a project to develop academic and professional skills which enable students to progress to year 2 and year 3. Although students were allowed to repeat the module and sit for the exam each year in case of failure, if a student ultimately could not pass APS, he/she would not be awarded an honours undergraduate degree even if he/she were to pass all other modules. Yet, from the micro perspective, despite every endeavour made in the previous years to support students in developing their maths skills, the rate of fail was rising each year. Figure 2 illustrates the situation.

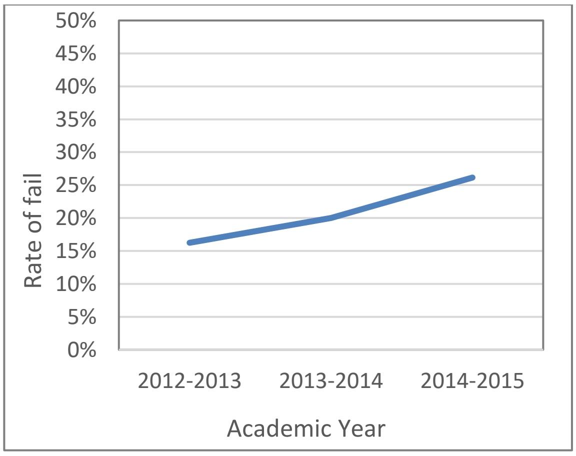


Figure 2: Performance in Maths (Rate of Fail) per Year

Based on unsatisfactory results and increasing rate of fail, the APS module leader decided to call for solutions that could solve the problem of students' performance in the APS module. This dissertation is a response to the call and is in line with strategic decisions made for first-year undergraduate students in order to develop their skills of maths problem solving and to improve their academic performance. Central to this research is the design and implementation of a soft-OR multi-methodology to enhance the application of an ongoing students' knowledge sharing process in an educational context.

1.2. Research Questions

Considering the problem briefly mentioned in Section 1.1.1, and based on the literature review of this research in Chapter 2, the researcher developed six research questions as below. The answers to these research questions intend to contribute to academic knowledge as well as practice.

Research Question 1: How can middle-ranked UK business schools strengthen their ability to understand and manage the complexities involved in knowledge sharing processes (for student learning) using a systemic multi-methodology?

Research Question 3: How can middle-ranked UK business schools enhance learners' skills development and performance improvement using a systemic multi-methodology?

Research Question 3: How can a systemic multi-methodology facilitate the design and development of effective knowledge sharing structures and processes?

Research Question 4: How can a systemic multi-methodology assist in uncovering and reducing structural fragmentations in a knowledge sharing network?

Research Question 5: How can social network ties shape a team's knowledge sharing skills and capabilities in a knowledge network?

Research Question 6: How can VSM theory support a network's cohesion in a knowledge sharing network?

In order to answer these research questions, the researcher intends to design a realistic and practical approach for complexity management in a knowledge sharing project within a UK-based business school. The proposed research methodology aims to provide the foundation for knowledge sharing and learning processes, which assist the learners in advancing their skills and in improving their performance.

1.3. Research Scope

The scope of this research is within a business school in a UK middle-ranked HEI. Within the business school context, this research will concentrate on an Academic and Professional Skills module, which is a strategic module for first-year students of undergraduate degrees. The APS module is designed to facilitate the transition of learners from secondary education to the HE system. The APS module aims to enable the learners to manage the academic complexities of their studies in the second and third years of undergraduate degree as well as their future studies or employment. Within the APS module the focus is placed on APS-Maths. It involves face-to-face maths learning and skills development. Details about the scope of the research in terms of the background of students in the context of APS-Maths is provided in Chapter 4.

1.4. Structure of the Thesis

This dissertation is structured in six chapters, namely introduction, literature review, research methodology, case studies application, discussions, and conclusion.

Chapter 1: Introduction

This chapter (current chapter) provides the preliminary knowledge about the focal topics and area of research. It briefly sets the background, context and the organisational problems that need solving, as well as the research questions and scope of the study. The structure of the thesis is discussed here and maps the flow of information provided.

Chapter 2: Literature Review

This chapter provides a literature review through different sections covering perspectives from different disciplines, since the present research is of a multidisciplinary nature. The chapter covers: 1) knowledge and knowledge management; 2) knowledge sharing and social network analysis; 3) a review of systems thinking research for knowledge sharing; 4) a reflection on the three previous sections and a review of studies concerning the context of this research. Overall, the literature review provides focal and instrumental theories used in this action research.

Chapter 3: Research Methodology

This chapter comprises two sections. The first section reveals the philosophical assumptions, whilst the second section provides the details of the design and development of the research methodology. The result is a multi-methodology for a Soft Canonical Operational Research (SCOR).

Chapter 4: Soft Canonical Operational Research (SCOR) Case Studies

This chapter starts by examining the external environment to understand the area of concern. It then presents two cyclical case studies, each developed through five stages of diagnosis, planning, implementing, evaluating and reflection/learning. The diagnosis stage uncovers some of the key issues that need to be addressed. The planning stage relates to preparations and plans of action for addressing the problems. The implementation stage provides the details of actions that were performed as per action plans. The evaluation stage shows the findings and results of the qualitative and quantitative data analysis. The reflection/learning stage brings to light the lessons learned and insights/understanding based on stages of the research.

Chapter 5: Thesis Discussions

This chapter is divided into five themes, each discussing one of the main subjects of the present research. There are discussions on each of the following: (1) assessing the design of soft-OR multi-methodology, (2) using a soft-OR multi-methodology approach, (3) VSM+SNA as a combinative tool for learning about complexity, (4) VSM+SNA for knowledge leadership development and autopoiesis, and (5) evaluating the multi-methodology action/operational research. The final theme relates to effectiveness, robustness, legitimacy, rigour/quality, and transferability of the study.

Chapter 6: Thesis Conclusions

Answers to the six research questions are provided in this chapter in detail. Moreover, contributions to knowledge and practice are presented. The chapter ends with the limitations of this research and implications for further research.

1.5. Summary

The researcher, being a mathematician and a system analyst, was inspired to perform this research. Her intention was to design and develop a soft-OR methodology for the practice of maths knowledge sharing. The cybernetic and systemic foundations of the methodology could support and ground her teaching and facilitative learning work in order to reproduce the benefits of such a specific methodology. These foundations could also be beneficial for other researchers and practitioners in terms of providing insights and greater understanding in the organisational context and educational environment.

Chapter 2: Literature Review

2.0. Introduction

This chapter provides the literature review for the present thesis. The research aims to design, develop and implement a systemic multi-methodology for the "Process of Knowledge Sharing". Hence, this chapter is divided into four sections in order to provide the background literature and conceptual analysis for the multi-dimensionality of this study.

The process of knowledge sharing is at the heart of this thesis and critical to such research is the very concept of knowledge. Section 1 therefore revolves around the definitions, concepts, typologies and taxonomies of knowledge as well as the definitions, patterns, structures, and process mechanisms of knowledge sharing.

Section 2 relates to the literature on knowledge sharing and social networks, focusing on the definitions, concepts and typologies of social networks of knowledge. It then provides a literature review on social network analysis.

Section 3 relates to the systemicity of the research and provides a literature review on systems thinking and the complexity perspective towards knowledge sharing. In this vein, the review focuses on the viable system model as a suitable facilitative tool for complexity handling in the process of knowledge sharing.

Reflecting on Sections 1, 2 and 3, the theories, ideas, and thoughts are wrapped up in Section 4 to form the "Framework of Theories and Ideas" that is required for the action research. Said framework includes reflections, theoretical boundary clarifications and a combinative perspective of VSM and SNA. Following this, a literature review on the context of learning is provided. Subsequently, an action framework of research in a learning context is illustrated and research questions are presented.

2.1. Section 1: Literature Review on Knowledge and Knowledge Management

This section relates to the literature review on knowledge and knowledge sharing. The definitions, concepts, typologies and taxonomies of both knowledge and knowledge sharing are conferred. The review also provides patterns, structures, channels and process mechanisms of knowledge sharing. Knowledge sharing outcomes/results are then discussed. The section concludes with a reflection on the debates in the literature in order to bring to light the research issues.

2.1.1. Knowledge: Definitions and Concepts

There are many and varied definitions of knowledge in the literature that are based on different contexts and epistemologies. No conclusion has yet been reached for a generally-accepted definition of knowledge. Plato defines knowledge as "justified true belief" (as stated in Small and Sage (2005)). While the focus of Plato's definition is on "truthfulness", Nonaka (1994) considers knowledge as personal belief that can be justified. The focus in his definition is on "justification" (p.15). The difference between the two definitions is that the former relates to the static nature of knowledge and of absolute form, expressed in the shape of logic. The latter perceives knowledge as a dynamic process in which a human justifies his/her personal beliefs and as such is part of aiming for the truth. To this extent, knowledge as an intangible resource in said view exists within the mind of the individuals. From a resource-based viewpoint, since individuals are working and collaborating together in the organisations, they exchange knowledge and information based on their tasks/roles and establish team knowledge as well as organisational knowledge. According to Nonaka (1994), knowledge exists at individual, group, organisation and inter-organisation levels. The information exchange/knowledge sharing among individuals facilitates a dynamic knowledge creation sphere. Organisational knowledge emerges in the shape of an organisational capacity that supports and motivates collectives/groups and individuals to act towards the shared goals/objectives. Nonaka and Takeuchi (1995) and Sveiby (1997) explain that knowledge amplifies the organisational capacity in order to achieve viable action. The focus of this definition is on the action element. It is only through action that the capacity to act can be discovered. Such capacity to act is also referred to as an intangible resource in organisations.

From a systemic perspective, Maturana and Varela (1980) define knowledge as:

"The question, 'What is the object of knowledge?' becomes meaningless. There is no object of knowledge. To know is to be able to operate adequately in an individual or cooperative situation" (Maturana and Varela, 1980, p.53).

This means that "all doing is knowing and all knowing is doing" (Maturana and Varela, 1992, pp.27). It is through structural coupling, i.e. actions and interactions of an individual with his/her environment as well as the individual's experiential processes (self-reference), that knowledge is created.

Along a very similar line, Davenport and Prusak (1998) offer a well-detailed definition of knowledge which has been adopted widely in the literature. They state that:

"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" (Davenport and Prusak, 1998, p.5).

Sheffield (2009) analyses this definition using three perspectives of knowledge management, i.e. the systems perspective, the research paradigm and the knowledge perspective.

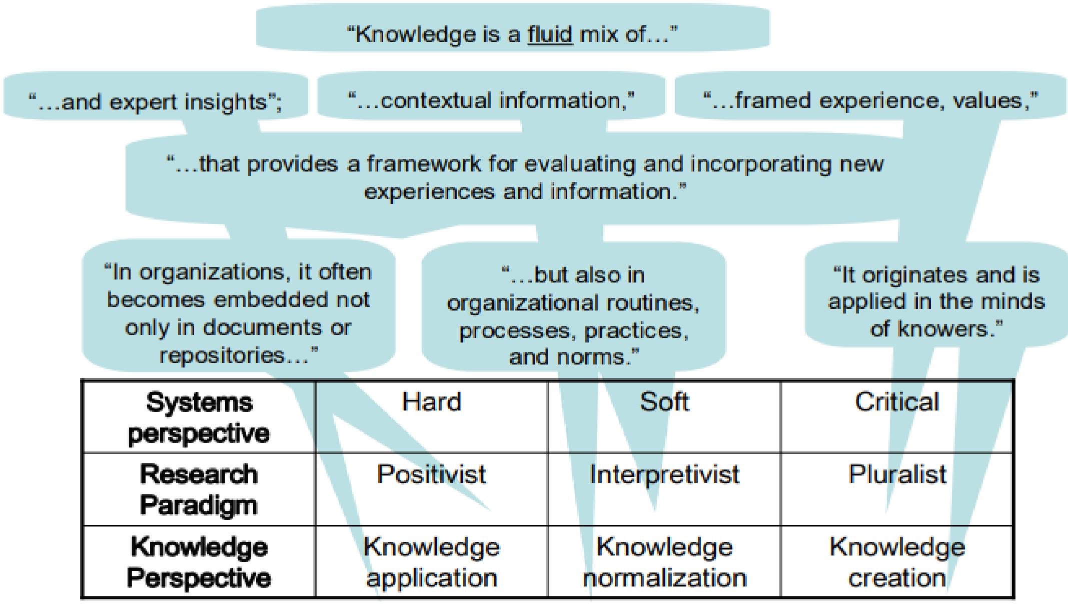


Figure 3: Davenport and Prusak's (1998) definition of knowledge analysed by Sheffield (2009) in EJKM, p.388

Sheffield (2009) explains that expert insights constitute the emergent knowledge and comprise representations of knowledge or boundary matters. Expert insights are referred to as explicit knowledge (Zack, 1999), and are available to members of communities, both local and global. In addition, knowledge originates from the mind of the knower and his/her diverse cumulative actions. Such actions then shape the organisational processes, routines and norms. Further, considering the context in which knowers' experience and specific values are framed, the personal aspect of knowledge is captured as tacit knowledge (Polanyi, 1966).

Cilliers (2002) refers to knowledge, from an ontological and epistemological combinative perspective, as a complex phenomenon and argues that we cannot know complex things completely. He states that millions of nonlinear interactions cannot be kept track of by anyone or any of the current technologies, in order to provide us with the evidence required to describe complex things. The subject of knowledge (i.e. the knower) is also within the world and simultaneously reflecting on the world in a contextualised way. From one side, these intertwined processes comprise an infinite number of interacting factors and conditions. From the other side, the context binds the number of aspects and circumstances, and thereby meaning making for the knower becomes possible.

According to Rajagopalan and Midgley (2015), forms of knowing held in symbolic ways, as well as practical capabilities and experience, can be captured through boundary critiques and boundary shifts; therefore, with a change in the context, new boundaries are in place and so the new meaning, and in turn the new knowledge, emerge. Confronting these boundaries and shifting them based on different perspectives, levels and depths, is what science is about, in order to generate new meaning and therefore new knowledge.

Reflecting on the above, this research will follow Davenport and Prusak's (1998) definition of knowledge, since it is in line with the systemic definition offered by Maturana and Varela. It is also an elaboration of it which includes the knowledge at the organisational level. Further, it is subjective and observer-relative.

2.1.2. Knowledge: Structure, Typologies and Taxonomies

There exist varied classifications for knowledge in the literature. In a comprehensive literature review, Alavi and Leidner (2001) reveal that knowledge may be viewed from six perspectives, namely as an object; as a state of mind; as a condition of having access to information; as a process; as a capability; or as a combination of data and information. The object view of knowledge suggests its storage and manipulations. The state of mind perspective refers to when knowing is conditioned by understanding and is achieved through experience, education, observation or discovery (Schubert et al., 1998). Therefore, the focus is to empower people in order to develop their individual knowledge and relate it to needs of the organisation. In a scenario based on knowledge as an outcome of information accessibility (McQueen, 1998), organisational knowledge must be managed so as to enable accessibility and recovery of the contents. The process perspective on knowledge attends to the application of expertise, i.e. knowing alongside acting (Carlsson et al., 1996; McQueen, 1998; Zack, 1998). The capability perspective refers to knowledge as a capability that potentiates the future actions (Carlsson et al., 1996). However, Watson (2008) suggests that knowledge is not much about capability. It is more about the capacity to apply information, and to learn and gain experience, based on which skills for understanding the information, determining necessary information and making decisions are developed. The last viewpoint on the concept of knowledge refers to interlinks between data, information and knowledge and asserts that data is related to basic quantifiable objects and information is a class or grouping of data which finds meaning through structures. These meaningful structures are then strengthened in a suitable context and become knowledge.

The precedence from data to information and to knowledge is believed to be linearly ordered. Davenport and Prusak (1998) put forth the believe that knowledge is derived from information and information is derived from data. However, Tuomi (1999), on the opposite side, asserts that there exists no isolated thing as data, unless it has been created through someone by means of his/her knowledge. In this scenario, data can emerge last and as a by-product. Information is also only created when there is the presence of knowledge. Knowledge is regarded as cognitive artefacts within an assumingly existing socially shared practice which uses these artefacts. It appears that the precedence in the structure offered by Tuomi (1999) is also linear, yet in the reverse order of the aforementioned structure. In the arena of data-information-knowledge structure, some authors, such as Igonor (2002), broaden the definition of knowledge to include intelligence or wisdom. In his view, information is based on considering the connections between elements of data, which relates to the perspectives of what, who, when, and where. Knowledge refers to understanding the patterns in information and includes policies, practices, methods and procedures. Wisdom is about understanding the principles, ethos, values and morals, as well as embodying them. It also appears that there is a linear order in the data-information-knowledge-wisdom structure. In addition, as the level of understanding increases, the level of context independence also increases.

From the holistic learning perspective, Yang (2003) addresses knowledge using three perspectives, namely perceptual, conceptual and affectual. From the perceptual viewpoint, knowledge depends on personal observations and physical understanding of the environment via direct experience and engagement within a specific situation. From the conceptual perspective, knowledge is viewed as a schema of interlinked notions and concepts. The affectual outlook refers to knowledge from individual sentiments that a social agent attaches to specific objects. According to Yang et al. (2009), these three perspectives are interwoven together through a social agent’s consciousness about the reality, being reached via personal getting-to-know, cognitive, and psychological processing and emotional attachments. When it turns to organisational knowledge, Yang et al relate to these perspectives with three types of knowledge, namely practical knowledge (attached with the perceptual outlook), technical knowledge (associated with the conceptual perspective), and critical knowledge (refers to the affectual view).

From the practice perspective, Johannessen (2008) relates to knowledge based on ease of knowledge communication. He divides it into two categories, namely “relatively easy to communicate as information” and “difficult to communicate as information”. Those types of knowledge falling in the first category are then divided into two sub-groups of meta-knowledge (knowledge about process as well as product) and explicit knowledge (can be objective or subjective). The second category contains three sub-groups, specifically tacit knowledge (connoisseurship and apprenticeship), hidden knowledge (disposition to think as well as disposition to act) and relationship knowledge (both formal and informal). The knowledge typologies offered by Alavi and Leidner (2001), Johannessen (2008) and Yang et al. (2009) provide a rich perspective on types of knowledge. Further classification of these types of knowledge based on ontological and epistemological positions reveals more insights at each level (see Table 1). However, what strikes an organisation is how these different types of knowledge are connected. This is for the purpose of both performing organisational activities and reaching overall organisational goals as well as remaining viable over time. In fact, the critical goal is to ensure that knowledge, as a widely appreciated strategic resource (Teece, 1998), contributes to the viability of the organisation. In this arena, therefore, the process of knowledge sharing is vital for organisational success and its viability.

In their article, Achterbergh and Vriens (2002) reveal the lack of research on the relationship between managing knowledge and the viability of the organisation. They ask what kind of knowledge an organisation requires to remain viable. Their investigations into knowledge management and the viable system model of Beer (1985) lead to defining domains of viable knowledge for an organisation. In this perspective, any organisation of purposeful activities must determine these domains of knowledge and their relations with each other to remain viable. This is realistic, no matter whether it is a goal-orientated personal activity, teamwork, or an organisation-wide practice (see Table 2). It is evident that knowledge domains defined by Achterbergh and Vriens (2002) provide a practically outcome-based typology of knowledge. Since outcome orientation is a feature in each domain as well as in the whole identity and governance of the organisation, this typology even goes further to recognise alignment among domains of viable knowledge, including and towards overall organisational goals.

Philosophical Stance	Type of Knowledge	Alavi and Leidner (2001)	Johannessen (2008)	Yang et al. (2009)
Epistemology	Cognitive Tacit	Mental Models	Hidden Knowledge	X
	Technical Tacit	Specific Know-how experience	Connoisseurship	Technical knowledge
	Explicit	Precisely uttered and generalized knowledge	Know-what Both objective and subjective	X
	Declarative	Know-About, Know-What	X	X
	Procedural	Know-How	Meta knowledge on Process - How we know	X
	Casual	Know-Why	Meta knowledge on Product - How we think	X
	Conditional	Know-When	X	X
	Relational	Know-Who, know-With	Know-who	X
Ontology	Individual	Created by and intrinsic in the individual	X	X
	Social	Created and Intrinsic to collective actions of a group	X	Practical knowledge
	Organisational	Best Practices	Communications	Critical knowledge: organisational policies, power distribution, economic gains, ethical standards

Table 1: Typologies of Knowledge based on ontological and epistemological positions

Domains of Viable Knowledge (Achterberg and Vriens, 2002)
Goals set by, Performance and Modus Operandi of the Primary Activity
Organisational Goal
Expected performance of the primary activity
Monitoring and control practices
Goal and Performance misalignment
Causes and Consequences of goal and performance misalignment
Actions to counter goal and performance misalignment in primary activities
Heuristics to implement counteractions
Anti-Oscillatory Measures
Interdependencies between primary activities
Actual Oscillations
Actual Performance Loss due to Oscillations
Norms for admitted performance loss due to oscillations
Gap between norm for admitted and actual performance loss due to Oscillations
Causes of the gap between admitted and actual performance loss due to oscillations
Experiences with anti-oscillatory measures
Problems and needs of the management of primary activities
Proposals for innovation made by intelligence
Desired goal for primary activities based on proposals for innovation
Gap between desired and current goals of primary activity
Required Capacity for reorganisation of primary activities
Actual Capacity reorganisation for primary activities
Gap between required and actual capacity for reorganisation of primary activities
Reviews by control of Proposal for innovation
Finalized plans for adaptation of organisational goals (A joint product of control and intelligence)
Regulatory measures to counter imbalance between control and intelligence
Developments in the relevant environment of the organisation
Norms for balance between control and intelligence
Actual imbalance between control and intelligence
Causes of imbalance between control and intelligence
Experiences with regulatory measures to counter imbalance between control and intelligence

Table 2: Domains of Viable Knowledge (Achterbergh and Vriens, 2002)

2.1.3. Knowledge Sharing: Definitions and Concepts

Existing literature does not reveal knowledge sharing as a well-defined construct (Wang and Noe, 2010; Sharratt and Usoro, 2003). This might be partly due to using data, information and knowledge interchangeably. According to Nonaka (1994, p.15), "information is the flow of messages while knowledge is created and organised by the very flow of information, anchored on the commitment and belief of its holder". According to Brown and Duguid (2000), there are at least three significant distinctions between information and knowledge based on (1) knowledge necessitates a knower; (2) it is much more difficult for knowledge to be detached and shared than information; and (3) it is much harder for knowledge to be assimilated and understood than information. Cabrera et al. (2006) state that "knowledge sharing" is used interchangeably with "knowledge transfer", "knowledge exchange" and "knowledge flow" in the literature. Lee (2001) defines knowledge sharing as "the activities of transferring or disseminating knowledge from one person, group or organisation to other" (p.323). Knowledge transfer is a term used mostly for knowledge exchange between different organisations or movements of knowledge between departments/divisions within the same organisation involving the knowledge source and the knowledge recipient for sharing and acquiring/applying the knowledge respectively (Szulanski et al., 2004). However, knowledge sharing is generally a term used when information and knowledge are exchanged among individuals within one institution (Bock et al., 2005). Knowledge exchange is distinguished from knowledge sharing as it involves both knowledge seeking and knowledge sharing (Cabrera et al., 2006). In the other words, knowledge sharing is an embedded process in knowledge exchange. Overall, it appears that the exchangeable use of these four terms might be a simple linguistic problem with its three characteristics of forms, meaning and context, which occur when definitions are to be provided as basic and understandable yet comprehensive descriptions for each of knowledge transfer, knowledge flow, knowledge exchange and knowledge sharing.

Ipe (2003) reveals the implications of using the term knowledge sharing and states that in the process of disseminating or presenting individual knowledge in a form and in such a way that it can be understood, absorbed and utilised by others, there are some conscious actions by the individual who possesses or owns the knowledge. The term sharing also suggests that the ownership of knowledge is not relinquished by the act of sharing but rather a joint ownership is developed between the sender and the recipient. In addition, according to Connelly and Kelloway (2003), knowledge sharing implies a notion of reciprocity and a relationship between the possessor and acquirer of the knowledge. Further, it implies that the possessor and acquirer of the knowledge are likely to be involved in synergistic collaborations towards a common goal (Boland and Tenkasi, 1995). Based on this notion, Connelly and Kelloway (2003) define knowledge sharing as a "set of mutual behaviours that involve the exchange of information or assistance to others" (p.294). Similarly, Cummings (2004) refers to knowledge sharing as providing information about the task as well as know-how to assist others and to team up and collaborate with others in problem solving, generating new ideas, and implementing policies and procedure. Van Den Hooff and De Ridder (2004) relate to knowledge sharing as a social process, i.e. "A process where individuals mutually exchange their (implicit and explicit) knowledge and jointly create new knowledge" (p.118). Similarly, a key driver for knowledge sharing in organisations is the process of communication and knowledge flows. Ku and Fan (2009) relate to knowledge sharing as a process of communication between two or more people to share and acquire each other's knowledge. According to Hsu (2006), shared knowledge comprises explicit knowledge (know-what and know-why) and implicit knowledge (know-how and know-who).

Reflecting on the debates above, based on Ipe's (2003) dissemination of individual knowledge, and given that Connelly and Kelloway (2003) and Van Den Hoof and De Ridder (2004) consider reciprocity of knowledge exchange and the joint creation of knowledge, this thesis puts forth a definition of the process of knowledge sharing as follows:

> *"Knowledge sharing is a social process of sharing and exchanging information in a reflective way among individuals, teams and organisation that leads to creation of new knowledge*, *relative to the receiver/observer's frame of reference".*

This definition highlights that knowledge sharing is a social process. It also states that such a social process starts with doing things together (acting) whilst exchanging/communicating information with each other at individual, team and organisational level. It involves understanding and making sense of information as well as reflecting and learning, through which information is transformed into new knowledge relative to how the receiver/observer absorbs it into his/her perspective.

In this vein, organisational knowledge comes into effect through individuals. In fact, according to Ipe (2003), the effective leverage of organisational knowledge is highly dependent on people. These people create, share, disseminate and apply the knowledge. Such leverage of knowledge is only viable when individuals share their knowledge and build on the mutual knowledge which emerges naturally when people are (meaningfully) acting together on specific tasks. Through connections between individuals, the process of interconnected activities in the organisation contributes to knowledge sharing and the move from sole possessions (individual minds) to shared ownership of knowledge (collective knowledge/wisdom) in teams and in organisations where it is converted into competitive advantages and economic value for said organisations. Importantly, and as Cabrera and Cabrera (2005) state, the extent to which knowledge is shared between individuals in organisations influences the knowledge at team and organisational level.

The definition offered above for the process of knowledge sharing in this thesis clarifies the importance of three knowledge levels, namely individual, team/group and organisation. It also illustrates the underpinning stance of this research in terms of the distinction between knowledge sharing, knowledge transfer, and knowledge flow and knowledge exchange.

Following the debates on knowledge and knowledge sharing as well as provision of a working definition for each of these concepts, it is necessary to review the literature to understand the advancements in terms of conditions, patterns, structures, mechanisms and processes, as well as the gaps in the literature.

2.1.4. Knowledge Sharing: Conditions, Patterns and Structures

A literature review concerning the conditions of knowledge sharing, as well as the patterns and structures of such a process, is provided here. Although the literature search brings to light the very volume of articles regarding knowledge management, a smaller number of articles attempted to focus particularly on knowledge sharing. The review first presents the motivation to share knowledge. It then relates to the three above-mentioned levels – individual, team and organisation – to further analyse the literature on each perspective.

2.1.4.1. Knowledge Sharing: Motivation to Share knowledge

Davenport and Prusak (1997) class knowledge sharing as a natural and voluntary act. This implies that an individual consciously engages in an act of knowledge dissemination even without any force to do so. However, he rectifies his stance later and states that "sharing knowledge is often unnatural", explaining that individuals perceive their knowledge as power and therefore are less likely to provide and share said knowledge. However, some researchers believe that thinking of knowledge sharing as a natural act is dependent on organisational culture.

Wang and Noe (2010) report that research on belief of ownership of knowledge in relation to knowledge sharing is very scarce and limited to only a few, such as Constant et al. (1994) and Kolekofski and Heminger (2003). When an individual in an organisation believes in his/her ownership of information, it is more likely that he/she will report that he/she would be involved and engaged in knowledge sharing activities. This might be as a result of personal contentment emerging from the act of sharing knowledge with others. The need for accomplishments and solidarity is also associated with the belief of knowledge ownership (Jarvenpaa and Staples, 2001).

Depending on how rich the knowledge sharing channel is and how capably an individual absorbs the information and learns from others, his/her attitude towards sharing knowledge would be influenced. The higher the absorptive capacity, the higher the chance of experiencing the advantages of knowledge sharing and the more positive the tendency to knowledge share (Kwok and Gao, 2005).

Further, there are positive relations between knowledge sharing attitude and the expectations that individuals have about the value of their knowledge, as well as with the expectations that they have about developing/improving their relationship with others through knowledge sharing (Bock and Kim, 2002). Knowledge sharing also increases with organisational aspects such as loyalty/commitment and work satisfaction (Lin, 2007). In addition, the senior manager's goal of encouraging employees to share their knowledge is positively associated with employees' knowledge sharing behaviour (Lin and Lee, 2004).

With reference to rewards for sharing knowledge, research shows that the benefits expected from knowledge sharing, such as incentives, respect and reputation, being evaluated against its costs, are associated with an individual's decision making on whether to share knowledge. For instance, participating and engaging in knowledge sharing in an online community of practice is associated with professional status, helping to improve the community, and with responsibility to give knowledge as a response to knowledge gains (Hew and Hara, 2007). However, for an individual, the belief of the usefulness of shared knowledge to others is more strongly correlated to knowledge sharing than personal gains which individuals may benefit from in the professional network (Siemsen et al., 2007). The perceived gains from technology-aided knowledge sharing can also positively impact knowledge sharing as opposed to fact-to-face activities (Bordia et al., 2006). However, lack of time and subject unfamiliarity are two cited factors which inhibit knowledge sharing in online professional networks (Hew and Hara, 2007). The amount of time needed to codify knowledge for the purpose of knowledge sharing is also positively associated with the likelihood of exploiting online knowledge resources for knowledge sharing. This is especially the case when the knowledge sharer has less trust in others, in terms of their contributions and utilisation of knowledge available in the online warehouse (Kankanhalli et al., 2005).

Knowledge sharing is also linked to trust and fairness as two main characteristics of interpersonal relations (Sharratt and Usoro, 2003). From the knowledge holder perspective, the process of knowledge sharing involves provision of knowledge to another individual, a group/team or a community whilst expecting reciprocity in return (Wu, Hsu and Yeh, 2007). According to Abrams et al. (2003), behavioural factors such as engaging in the collaborative communications and disclosing expertise and limitations, affect trust-building when sharing knowledge. However, the level of effectiveness of these factors depends on the culture of the organisation. Trust (Lin, 2007), and in particular dimensions of trustworthiness such as compassion, integrity and capability (Bakker et al., 2006), act as mediators for sharing knowledge. However, trust, can be a double-edged sword. Mixed results are evident when trust is placed in management only rather than in other individuals working at the organisations. Indeed, reference has been made to a scenario of mistrust causing potential knowledge users to avoid asking questions regarding the usefulness and the application of the shared knowledge, and in turn leading to misuse of knowledge (Renzl, 2008).

There is also a positive association between knowledge sharing and procedural fairness (Schepers et al., 2007). In addition, according to Lin (2007) both procedural and distributive fairness have an indirect relation to the sharing of tacit knowledge through organisational commitment. Further, knowledge sharing is related to distributive fairness indirectly through trust in peers.

2.1.4.2. Knowledge Sharing: Nature and Value of Knowledge

In terms of studying knowledge sharing, the majority of literature categorises knowledge into two types, namely tacit and explicit. This classification and the recognition of value attributed to different types of knowledge play key roles when it comes to the choice of method for sharing knowledge. Different types of knowledge, according to Lam (2000), are differentiated through three criteria: “codifiabilty & mechanisms to share”, “methods of acquisition and accumulation” and “the potential to be collected and disseminated”. Tacit knowledge is not easily codified. It can neither be utilised nor communicated (Polanyi, 1966; Nonaka, 1994). In fact, tacit knowledge is sticky and exists in the mind of the individual who possesses it. Therefore, it leads to an incremental expenditure for an organisation. The tacitness of knowledge and its stickiness in the mind of the knowledge holder from one side, and the absorptive capacity of the knowledge acquirer from another side, are causes of such expenses (von Hippel, 1994).

However, explicit knowledge is codifiable, storable, and can be spread out and communicated (Schulz, 2001). Explicit knowledge, in contrast with tacit knowledge, can be shared easily. Yet, there are other factors involved which mean that it is not so easy for the former to be shared. Explicit knowledge, as Weiss (1999) reveals, can be broken down into two types, namely rationalised knowledge and embedded knowledge. Rationalised knowledge is general and independent from the settings. It is public and standardised. An example of rationalised knowledge is guidelines of conducting a consultancy project. This type of explicit knowledge can be shared easily because it is readily available and is public. Embedded knowledge, on the other hand, is mostly personalised, sensitive, and context-laden with narrow applicability. Hence, embedded knowledge is not easily shared (Weiss, 1999).

It appears that the trend of the tacit-explicit divide in the literature has acted as a limiting factor against appropriate recognition of other types of knowledge as well as consideration of any significant development in advancing various methods of knowledge sharing with respect to the other types of knowledge.

Furthermore, regardless of the type, the value of knowledge also plays an important role in strategic decision-making regarding sharing knowledge. In fact, both individuals and organisations consider the value of knowledge and the significance of its ownership (Jarvenpaa and Staples, 2001). Perceiving knowledge as a valuable commodity, knowledge sharing turns into a process of decision making for individuals on what to share, how to share, who to share with and when to share (Andrews and Delahaye, 2000), as well as the development of emotional ownership (Jones and Jordan, 1998) which are rooted in individual reputations, status, and career outlook (Andrews and Delahaye, 2000). Individuals holding valuable knowledge are therefore expecting to be valued by the organisation (Jones and Jordan, 1998). For instance, knowledge developed in R&D is perceived as highly valuable due to its commercial advantages, scientific significance, patents, and research grants. According to Armbrecht et al. (2001), in such cases knowledge is perceived as power, and therefore it develops a dilemma. A highly valuable knowledge holder in this scenario receives the incentives to share knowledge from one side and the power of knowledge to reserve it from another side. Sharing such knowledge might reduce the value of the individual who possesses said knowledge, especially if this knowledge is his/her main source of value to the organisation. Therefore, he/she resists becoming involved in knowledge sharing activities. Uncertainty and insecurity (e.g. in mergers and acquisitions) felt by the knowledge holder can also affect his/her decision in sharing knowledge (Empson, 2001).

2.1.4.3. Knowledge Sharing: Dynamic Processes

From the dynamic perspective, the literature search shows that there is a very small account of knowledge on team characteristics and dynamic processes related to knowledge sharing. Studies reveal that a higher level of cohesiveness, as well as a longer period of existence of the team, increase the likelihood of knowledge sharing within members of said team (Sawng et al., 2006). In addition, knowledge sharing in a team is positively influenced by the leadership style of empowering (Srivastava et al., 2006). Further, agreeable and extravert styles of communication in the team are also positively linked to both willingness and behaviour towards knowledge sharing (De Vries et al., 2006).

With regard to team diversity, research shows that those who think of themselves as a minority in the team based on gender, education and marital status, are less likely to share knowledge (Ojha, 2005). The male-female ratio in the composition of the team also affects the likelihood of a person becoming involved in knowledge sharing. According to Sawng et al.'s (2006) study concerning the R&D teams of large organisations, the higher the male-female ratio in the team, the more likely a person is to engage in knowledge sharing. In addition, knowledge sharing in functionally diversified teams can be facilitated through acknowledging the expertise of team members (Thomas-Hunt et al., 2003). Further, disagreement with other members of the team and not contributing one's own exclusive knowledge are more likely to be problems for socially-isolated individuals in the team (Phillips et al., 2004).

From the perspective of individuals in the team, openness to experience is positively related to knowledge exchange and self-reporting at the individual level. In fact, those individuals who are highly open to experience are likely to demonstrate a high level of curiosity towards seeking other people's insights, reflections and ideas (Cabrera et al., 2006). In addition, individuals' comfort levels, as well as their computer skills, are likely to be linked with using online collaborative media for sharing information (Jarvenpaa and Staples, 2000).

Further, individuals who obtain a higher level of education and have more years of work experience are found to be more likely to not only have a positive attitude towards knowledge sharing, but also to actually share their expertise (Constant et al., 1994). Confidence in knowledge sharing skills is also likely to be related to expressing one's intentions to share knowledge as well as his/her higher level of involvement in knowledge sharing activities within the team (Cabrera et al., 2006). Further, anxiety about evaluation, according to Bordia et al. (2006), is negatively linked to knowledge sharing.

From the organisational network perspective, in the communities of practices, knowledge sharing might be embedded. The tie between individuals in social networks can be facilitative to knowledge sharing and improve the quality of information received (Cross and Cummings, 2004). Personal relationships and having direct connections with other individuals of a virtual community are also positively linked with the quantity and perceived usefulness of the knowledge which has been shared between them (Chiu et al., 2006). In addition, Chen (2007) states that in an online professional community, individuals are expected to sustain and strengthen their social ties for which they have to frequently participate in the community. Such expectation positively influences their intention to participate continuously.

Further, according to Perry-Smith (2006), weak ties are related to non-redundant information. Levin and Cross (2004) assert that weak ties are more beneficial to knowledge recipients compared to strong ties. Strong ties and social cohesion are positively linked with ease of knowledge transfer from the knowledge holder's point of view. It is expected that social connections with recipients of knowledge will encourage the knowledge holders to share their knowledge. In the same vein, Kankanhalli et al. (2005) indicate that the existence of social network connections as well as social capital within a community of practice can aid in knowledge sharing.

2.1.4.4. Knowledge Sharing: Organisational Context

Within the scope of the organisational context, trust is the focal point of studies (Wang and Noe, 2010). According to Kankanhalli, Tan and Wei (2005), a culture based on trust can reduce the negative effect of knowledge sharing. Organisational trust culture is associated with individual knowledge sharing and the implementation of an internet-based knowledge management system (Willem and Scarbrough, 2006).

While cooperative teams cultivate trust as an essential condition for knowledge sharing, an organisation with an individual competition culture can inhibit knowledge sharing (Willem and Scarbrough, 2006). Organisational cultures that promote innovation are more likely to use subjective norms to support knowledge sharing (Jill et al., 2003).

Through a qualitative research project with 50 organisations, De Long and Fahey (2000) discover that if established organisational values do not support knowledge sharing between the units of organisation, the gains from new technology infrastructure will be restricted.

Further, learning culture is assumed to have a positive effect on knowledge sharing, yet the literature reveals mixed results for such studies. According to Taylor and Wright (2004), an organisational culture that encourages individuals to learn from mistakes is more likely to lead to successful knowledge sharing among employees. Continuous learning activities are important for the purpose of knowledge sharing (Hsu, 2006). Nonetheless, according to Lee et al. (2006), there is no significant association between knowledge sharing and an organisational climate that is learning-orientated towards trying new things. There are also mixed findings regarding the relationship between knowledge sharing and norms of reciprocity in the online professional community. On the one hand, according to Chiu et al. (2006), an individual's knowledge sharing is positively affected by norms of reciprocity. On the other hand, Wasko and Faraj's (2005) case shows a negative link.

The literature also reveals that support received from management (e.g. trust) can improve perceptions of employees regarding knowledge sharing culture as well as employees' enthusiasm for knowledge sharing (Lin, 2007). The level and quality of knowledge sharing are also affected by management support through its impact on employees' commitment to knowledge management (Lee et al., 2006). Employees' self-reported knowledge sharing is also positively associated with the manager's control of rewards for desired behaviour and the employees' belief in the manager's knowledge and expertise in the area (Liao, 2008). Further, knowledge sharing among employees as well as improving their views on knowledge sharing can be supported through encouragement from their managers and peers (Cabrera et al., 2006).

To establish a supportive culture and facilitate knowledge sharing, solutions based on incentive such as rewards and recognition are recommended (Nelson et al., 2006). Lack of incentives is one of the main obstacles standing in the way of the dissemination of knowledge across cultures (Yao et al., 2007). Kankanhalli et al. (2005) state that the frequency of contributions to knowledge in knowledge management systems is dependent on organisational incentives such as higher salary, promotion and bonus. This is particularly the case when individuals are identified characters within the organisation. Those employees who think that a higher level of rewards motivates them to participate in knowledge sharing and utilisation/application, have a greater tendency to suggest that the knowledge management systems contain helpful contents (Kulkarni et al., 2006). In addition, Kim and Lee (2006) report on the performance-based pay system and its positive link to knowledge sharing. On the other hand, research shows that attitude towards knowledge sharing cannot be manipulated by expected incentives (Bock et al., 2005). There are also studies which suggest no relation between motivation based on incentives and attitude towards knowledge sharing (Lin, 2007). For example, Jin Chang et al. (2007) reveal no link between rewards based on performance outcomes as well as adequate incentives and knowledge sharing between team members on a product development team. It appears that these conflicting results might be somehow due to the effect of a moderator such as contextual situations or even personality of those involved – an area which seemingly lacks an established account of research in the literature. To examine whether type of incentive affects knowledge sharing, Ferrin and Dirks (2003) use a dyadic decision-making scene in a lab experiment. They discover that a system of rewards based on cooperation can positively influence knowledge sharing among partners. In addition, they find that the result for a system of incentives based on competition is opposite. The influence of group-based incentives also outperforms the impact of piece-based rewards in terms of the former's positive relation with knowledge sharing (Taylor, 2006). Further, when individual-based incentives in an organisation increase, then a stronger positive association between group-based incentives and the perceived incentive for knowledge sharing is developed (Siemsen et al., 2007).

In terms of organisational structure and knowledge sharing, research shows that an organisational structure which is designed to reflect the functional segmentation is likely to inhibit knowledge sharing both across organisational tasks and within communities of practice (Tagliaventi and Mattarelli, 2006). A less centralised organisational structure is, however, facilitative to knowledge sharing (Kim and Lee, 2006) and provides an encouraging open space environment among employees (Jones, 2005). It also assists with the use of the job rotation technique (Kubo et al., 2001) and motivates individuals to communicate across functions and have informal gatherings (Yang and Chen, 2007).

2.1.5. Knowledge Sharing: Channels and Process Mechanisms

Knowledge cannot be shared successfully without a channel and a well-thought-out mechanism or a designed process. A literature review of the knowledge sharing channels, mechanisms and processes is provided here.

2.1.5.1. Knowledge Sharing Channels

Knowledge can be shared formally and informally. The formality of such a process depends on the nature of knowledge, as well as the location and settings of the sharing channels that embody the spread of knowledge.

Formal channels create both the context for knowledge sharing and the necessary tools for individuals to carry out this sharing. However, these channels mainly focus on sharing explicit knowledge (Nonaka and Takeuchi, 1995; Rulke and Zaheer, 2000). Formal knowledge sharing is considered an opportunity with the intention to share a body of knowledge and is more likely to happen in training sessions, workshops, formal seminars, and educational classes (Kwok and Gao, 2005), as well as in structured work teams and technology-based systems (Ipe, 2003). Bartol and Srivastava (2002) relate to formal knowledge sharing as “formal interactions”. Rulke and Zaheer (2000) view formal knowledge sharing through the learning lens and refer to it as a “purposive learning channel” which is designed to clearly obtain and disseminate knowledge. These channels provide structured environments and connect a large number of individuals through fast dissemination of knowledge using online and technology-based network systems. Indeed, there is empirical and successful evidence which supports knowledge sharing through formal channels (Hickins, 2000). Formal knowledge sharing solutions, as Okhuysen and Eisenhardt (2002) state, range from basic instructions to more complex techniques such as Nominal Group and Delphi.

Examples of the informal settings are casual workshops, coffee break conversations, and spontaneous meetings (Alavi and Leidner, 2001, p.120) through promoting social interactions between individuals, e.g. among colleagues in an organisation (Holtham and Courtney, 2001). Networking with other specialists, face-to-face communication, written correspondence, or even documenting, organising and capturing knowledge for others are also regarded as informal knowledge sharing (Cummings, 2004). Furthermore, Stevenson and Gilly (1991) state that individuals are more likely to use informal relationships for communication, even when organisations provide designated channels for communication. Informal channels, including social networks and personal relationships, can facilitate learning and knowledge sharing (Nahapiet and Ghoshal, 1998), and that is why Rulke and Zaheer (2000) relate to them as “relational learning channels”. Research shows that most knowledge is shared informally and through relational learning channels (Pan and Scarbrough, 1999), which also allow for the building of trust, respect and friendship (Nahapiet and Ghoshal, 1998). Granovetter (1992) reflects on relational learning channels and refers to them as “relational embeddedness”, which is a type of personal relationship that individuals build up when they interrelate with others for a period of time. According to Brown and Duguid (2000), shared learning occurs in complex and collaborative practices within informal networks in communities of practice.

2.1.5.2. Knowledge Sharing Mechanisms

There are a number of mechanisms for knowledge sharing based on which strategies, solutions and activities can be developed. Table 3 summarises some of the key process mechanisms.

Knowledge Sharing Mechanisms	Example Authors	Description
Peer assist	Cummings et al (2013); Gratton and Ghoshal (2005); Collison and Parcell (2001);	Peer assist is an approach for teammates to get together and provide feedback and advice on each other's work or to clarify the issues as well as to reflect on their observations and experience and to learn some lessons. It is a mechanism, which is easily adaptable to the desire of the team members. It motivates the social interactions and facilitates learning among peers (Collison and Parcell, 2001).
After action review	Sawyer and Deering (2013); Baird et al. (2000)	After-Action review was developed in US military and is an after an event mechanism to assess the outcomes of the event and decide on the lessons that could be learned in order to avoid the occurrence of similar mistakes later (Morrison, 1999). The learning emerge in this way is associated to the concept of "prevention is better than cure". Participation and enthusiasm to offer personal tacit knowledge are key to the success of after-action review mechanisms for knowledge sharing.
Intranets and extranets	Behera (2013); Watson (1999); Tang and Lu (2002)	Intranet and extranet are considered as knowledge sharing platforms. Intranet provides access to information for the insiders and extranet provides information to the outsiders of an organisation. Though using similar technologies, intranet is a limited type of internet. Only employees in an organisation use it. Extranet use the same infrastructures but it allows some access to the external users for communication and collective working.
Knowledge fairs	Harris (2009); Ferreira and Neto (2005)	Knowledge fairs are mechanism for themed knowledge sharing. It uses presentations, knowledge kiosks, and demos. This is a time consuming and not a cost-effective mechanism, hence it is important to buy-in the management for implementation. Knowledge fairs are useful for networking. If effectively implemented, they can facilitate simultaneous information presentation however, they might cause information overload.
Mentoring	Hudson (2013); Lawrence (2008); Bryant (2005)	Mentoring is a mechanism, which focuses on the relationship between mentor and mentee in terms of learning support and direction through sharing knowledge. The mentor is an expert and experienced person who helps the less informed and less experienced ones. The mentoring approach is future-oriented and permits further development of communications. If implemented in an organisation, it facilitates the increase in productivity and understanding of working environment.
Coaching	Grant (2014); Nash and Collins (2006);	Coaching is a process that aims at advancing personnel's specific skills and capabilities of based on the need of each individual in the organisation. It differs with mentoring because it is employee-centred and the coach does not deliver her/her vision agenda to the individual under coaching. Coaching increases the confidence of the employee. Employee is empowered to learn the know-how and in turn, his/her success is increased.

Formal group-based knowledge sharing	Beddoes and Borrego (2014); Cordery et al. (2009); Garcia-Lorenzo et al. (2003); Okhuysen and Eisenhardt (2002)	Formal team-based approaches are focused on integrating the personally own knowledge at individual level to the team and collectives' levels (Garcia-Lorenzo et al, 2003). The success of team-based sharing in terms of improving collective knowledge, bringing creative ideas and solving the issues and problems is mediated by information sharing, time management as well as questioning other teammates (Okhuysen and Eisenhardt, 2002).
Storytelling	Haines et al. (2015); Smith, (2012); Tobin and Snyman (2008)	Storytelling refers to a knowledge-sharing tool based on which a journey containing a series of events are told. It facilitates the organisational process of knowledge sharing (Tobin and Snyman, 2008) and can be a transformation management mechanism (Smith, 2012).
Communities of practice	Wenger (2011) Duguid (2005)	Communities of practice is a process mechanism for people to frequently gather and share their desire to find and solve a problem or focusing on certain topics, to learn and to increase their understanding. Community of practice has to have three features of (1) practice, (2) community and (3) domain (Wenger, 2006).
Knowledge cafes	Singh (2015); Gurteen (2009); Dvir and Pasher (2004)	Knowledge Café represents where a process of interaction occurs among individuals who have similar issues or interests. They gather first as small groups and then they contribute as one unit to reach a better understanding and to solve an issue. Gurteen (2009) states that knowledge cafés are featured by guest speaker for five to thirty minutes, a basis for conversation through open-ended question, small groups of people to debate on the topic, as well as a large reflective feedback session.
Knowledge network	Barnhardt (2014); Amine Chatti (2012); Hansen (2002);	Knowledge network is a gathering for a group of people with similar interests on a specific subject in order to share, increase and build their knowledge. Knowledge networks are similar to communities of practice; However, they are not generally time-limited like communities of practice (Hansen, 2002).

Table 3: Process Mechanisms for Knowledge Sharing (Adapted from Lefika and Mearns, 2015)

2.1.6. Reflection on the literature and Research Issues

Through a reflection on the above discussions, it is evident that there is a need to develop studies to better understand how diversity of team members can be involved in knowledge sharing processes and how this would influence the performance in the team as well as in the organisations. Based on Marks, Mathieu and Zaccaro (2001), it is interesting to research how both the type of knowledge and the interval that knowledge is being shared are influenced by the development stage of the team. Such a study would provide a better understanding of whether or not team members are involved in many and varied management tasks.

In addition, whilst organisational culture is important, studies have to move from cultural dimensions and focus more on how knowledge sharing dynamics as well as learning at individual and team levels are influenced by a culture that promotes knowledge sharing.

Further, although human resource practices such as performance evaluation, training, and rewards may facilitate the building and changing of organisational culture and may regulate employees' behaviours (e.g. Swart and Kinnie, 2003), there is a lack of research on how communities of practice can set up and create the cultural norms.

Moreover, relatively less research has utilised the structural holes theory and network closeness theory. Thus, the question arises: how can these theories enhance knowledge sharing in the groups, in the organisations and in the communities of practice? Using these theories helps to acknowledge that individuals in the organisation are not performing their job duties in isolation. They are embedded in the social network.

Finally, with regard to the method of knowledge sharing, few studies have examined the differences between knowledge sharing via knowledge management systems and face-to-face interactions. This is important because the factors which influence the decision to share knowledge in face-to-face versus technology-aided interactions are likely different, e.g. employees who are highly extraverted may be more likely to share knowledge in a face-to-face compared to an electronic context, because knowledge exchange is more relationship-based. The same is true for knowledge sharing communities. In addition, there is a lack of research which examines how different the advantages and disadvantages of face-to-face sharing communities are from those of online knowledge sharing communities. This is particularly because face-to-face sharing is still a crucial way of sharing the sticky tacit knowledge. Data collection in the online community of an organisation can be carried out through capturing the knowledge sharing history or records. An objective method of evaluation can be designed to assess the dimensions of knowledge sharing (Wasko and Faraj, 2005). However, this approach only takes parts of the knowledge sharing which has happened in the online community space/forum/system. It ignores and does not capture the knowledge shared face-to-face. In order to increase the validity of measures (which evaluate knowledge sharing), there would be the need for a combination of systems’ records of knowledge sharing and a type of scoring that can be provided by peers or superiors. Measuring the subjective perspectives and objective aspects of knowledge sharing are both important in recognising the degree to which self-rating (on knowledge sharing) is similar to the objective evaluation of shared knowledge through KM systems. More studies are to focus on the objective measurement of shared knowledge, yet designing such studies might be challenging.

Having reviewed the above, this section (Section 1) was a conceptual exploration to present the definitions, concepts, characteristics and typologies of knowledge and knowledge sharing. In addition, it highlighted the channels and mechanisms of knowledge sharing. Further, the relevant literature regarding the methodological perspective used in research on knowledge sharing was explored. Through this comprehensive literature review, the key concepts of the first dimension of the present interdisciplinary research (i.e. knowledge and knowledge sharing) were covered.

The next section (Section 2) will focus on the second dimension, which relates to the knowledge sharing and social network analysis. It provides a review of literature on the basic concepts of social networks and their typologies, as well as literature concerning methods of social network analysis, both qualitative and quantitative. It then refers to literature on combining the qualitative and qualitative social network analysis.

2.2. Section 2: Literature Review on Knowledge Sharing and Social Network Analysis

In this section, the literature review relates to social networks, knowledge sharing networks and social network analysis. The definitions, concepts, typology, levels and measures, as well as their significance, are debated. The discussions on knowledge sharing through social network analysis then proceed with quantitative and qualitative methods for such analysis.

2.2.1. Social Networks: Definitions, Concepts and Significance

Jelassi et al. (2014) relate to social networks as “a set of entities inter-connected with each other”. They emphasise that the entities are generally actors or organisations and the relations depict their interactions. Wasserman and Faust (1994) also refer to social networks as a set of agents and a set of links representing relationships among them. Merchant (2012) states that social networks are “a way of conceptualising social groupings and interactions”. He opines that social networks are informative in terms of the patterns of everyday practices of social interactions among individuals in neighbourhoods and communities.

Examples of social networks include current or previous school friends, colleagues or club members. Belonging to the same school, organisation or club provides the vital context for individuals to develop, enhance and maintain their links with others, whether these links be friendship, a work relationship, or casual associations. Traditional societies are predominantly characterised by the face-to-face relations within nearby areas. This has changed due to advances in communication technologies. For example, communications through post or telephone in the past allowed people to keep their ties in discrete networks (Gillen and Hall, 2010). Newer methods of improving or changing/altering prior ties/links have now become possible with internet-based social networks, which allow people to keep in touch with friends, relatives or religious associations and to build on the ties. All of this advocates the use of the network metaphor to depict the social ties and interactions. A network captures the link between points and the directions of the links in a graph. In fact, a social human agent is reduced to a point, and connected to other points in the network; the network also shows the pattern of interaction among, for instance, friends, social groups, etc.

When social agents are in a network, they can regroup or rearrange their social connections depending on how the relations would better fit their circumstances. They also release/remove the ties that are highly tiered and hierarchical. In addition, social agents are able to fill in the structural gaps when there is a lack of ties in their social relations (Benkler, 2006, p.37). However, social interactions and individuals' role-plays are much more complex in real life.

Although the way in which social agents are connected together and the way they take part and build commitment and acquaintance formally and informally are central, their connections are also essentially important for the resources to flow and for the actions to take place in the environment. In this sense, more research is needed to better understand the way social networks are initiated and used in both physical and online environments. Future research could focus on the interplay and interactions between physical and online networks (Merchant, 2012). Since there are interconnections among individual social agents, social network analysis can visualise the issues and link micro and macro gaps in the patterns of resource flow in the network (Baron et al., 2000, p.19).

In the context of learning, the flow of information, knowledge and other resources between teams or groups has become very important. Therefore, communication by means of technology and media becomes central (Garton et al., 1997, p.1). In this vein, it is particularly interesting to investigate how knowledge, as an intangible and non-material resource, can flow and be shared throughout the social network. This perspective highlights the significance of knowledge-sharing social networks and the emerging patterns of change in the structure of such a social network.

2.2.2. Social Networks of Knowledge: Concepts, Characteristics and Typologies

The concept of knowledge sharing networks is rooted in knowledge management and relies on an organisation's knowledge base. Sharing the knowledge, insights and know-how among employees and establishing the knowledge sharing networks are vital for those organisations which intensively use knowledge. The literature reveals that codification and interaction are two ways to deal with knowledge sharing in an organisation. Knowledge codification requires a knowledge management system as well as relevant procedures on how and where to store the documents and exchange them when required. The interaction approach revolves around knowledge sharing between and among individuals, for which knowledge sharing networks play a major intermediary role. When using these two methods of knowledge sharing, organisational processes and routines, as well as the experiences gained by individuals, are considered important for optimal performance and creativity (Tsoukas, 2002). Knowledge sharing networks are crucial means for flow of knowledge (Appleyard, 1996). They are usually embedded within the institutions and are often recognised as 'communities of practice'. However, there are differences in their forms and purposes.

Knowledge management and social learning theory are the two frameworks through which knowledge sharing structures have been debated. However, the meanings associated with knowledge sharing communities and their key aspects and channels are different under the two frameworks. Central to the social theory perspective on knowledge sharing networks is the idea of 'practice'. Teams/groups share, obtain and create knowledge around this concept. What embody the accumulated knowledge are the routines, processes, symbols, etc. based on which the foundation for learning emerges. In contrast, the use of ICT and principles of managing domains of knowledge are central to the knowledge management perspective on knowledge sharing networks. Facilitated by ICT, the knowledge-sharing network of experts, specialists and professionals from different departments in the organisation (with shared interests on work issues) share their knowledge and form a community of practice (Verburg and Andriessen, 2011). Such communities, as Gongla and Rizzuto (2001) contend, are "institutionalized, informal networks of professionals managing domains of knowledge" (p.843). In the literature, knowledge sharing networks are termed "community of interest", "knowledge network", "epistemic community", "network of practice" and "knowledge community". Wenger (1999) refers to communities of practice and suggests that they are social structures which aim to advance the skills of their members through mutual interactions, shared practice and undertaking of joint initiatives. For instance, Hewlett Packard and BP have used communities of practice to encourage innovation and increase performance (Cross et al., 2006). Communities of practice are not the same as informal knowledge networks or communities of interest, because the informal networks and communities of interest are only for information exchange. According to McDermott (1999), the shared practice, along with the intensity of mutual engagements, are found to be the key defining factors for the development of identity in the communities of practice. They are self-organising entities and resist solutions from business managers. According to Brown and Duguid (1991), communities of practice are emergent. This means that the shape, identity and membership of these communities emerge and develop in the process of carrying out an activity of common interest, rather than communities being created to perform an activity. However, despite being emergent, organisations can support communities of practice through creating a facilitative environment. This would include gathering the right individuals together (Wenger and Snyder 2000). According to Juriado and Gustaffsson (2007), there are four main organisational mechanisms that foster and promote the emergence of communities of practice: (1) trust building stability; (2) competence contributors; (3) competence shadows; and (4) social glue.

Another form of community is the community of commitment, and these communities are contracted to deliver tangible outcomes. Therefore, they receive resources from organisations, and have rules and membership schemes, as well as a formal schedule of interaction meetings with planned target KPIs to deliver (Collison, 1999). Further, networks of practice, as Brown and Duguid (2001) discuss, constitute a type of knowledge network in which most individuals might never interact. There is no face-to-face interaction, nor a plan of actions to undertake, and hence there is no or limited knowledge creation, although these networks' work domain is similar and they just sometimes share knowledge. They can be large with global communication. Scientific associations are examples of these knowledge networks. From the knowledge management perspective, knowledge sharing communities can be dispersed geographically, since they can be connected through ICT to share and create knowledge (Botkin, 1999). However, Wenger et al. (2002) state that these communities have to be managed through the cultivation and creation of a knowledge sharing culture rather than through giving direction and order. Some characteristics of knowledge sharing communities include:

> *"Being global in scope, being responsible for a domain of knowledge, adopting a small set of common rules for managing knowledge, providing opportunities for sharing tacit knowledge among community members, using the common enterprise-wide data management application, being sponsored by a business unit and not being an organization unit or team" (Gongla and Rizzuto, 2001, p.843).*

Verburg and Andriessen (2011) bring to light the key features of knowledge sharing networks. Table 4 shows these features.

Characteristics	Description
Purpose	• Shared mission vs. information sharing only • Organisational orientation (finding best practice, innovative solutions) vs. individual orientation (information exchange for responding to personal problems)
Contract Value	• The extent of obligation for delivering tangible results
Formalisation	• Formal vs. less formal meetings • Formal establishment and management: appointment of coordinator
Boundary	• Closed vs. Open community • Fixed vs. flexible membership
Composition	• Experts only vs. Newcomers and Experts both
Reciprocity	• The extent of interactions and familiarity among members
Identity	• Sense of belongingness, trust, cohesion,
Size of the Community	• Large vs. Small
Organisational structure	• Intra vs. inter organisational
Geographical Dispersion	• Local vs. Geographically distant
Mode of Interaction	• Face-to-face vs. Via ICT

Table 4 : Characteristics of knowledge networks (Verburg and Andriessen, 2011)

Using the key characteristics and two measures of proximity and institutionalisation, Verburg and Anderiessen (2011) analyse 38 examples of knowledge sharing networks to find the basic types. Their findings clarify four basic types of knowledge network, namely (1) informal networks of knowledge, (2) Q&A networks of knowledge, (3) strategic knowledge networks, and (4) online strategic knowledge networks. These four basic types of knowledge networks point out differing ways in which the networks should be organised and supported. Informal networks of knowledge have a high level of communication and interaction, though they are less formal and mainly serve for the exchange of information and knowledge among individuals. Q&A knowledge networks have an intermediate level of interaction and are less formal. However, their major purpose is to solve problems on a daily basis. Strategic networks are size-limited but very formal, and are highly interactive. Their basic focus is on increasing the spread of knowledge in the organisation. Online strategic knowledge networks are the online version of strategic networks, but are managed and facilitated by ICT for the interactions.

Having set out the clarifications of the typologies of knowledge networks, it is now important to look at the concepts and theories of social network analysis which have been widely developed.

2.2.3. Social Network Analysis: Definitions and Concepts, Scope of Knowledge Sharing

Social network analysis (SNA) is an instrument with which patterns of interaction can be studied and social structures can be described. Burt (1978) refers to SNA as an assessment method through which to study social relations. This method is, however, much less effective when it comes to examining individual attributes. Cross et al. (2001) define social network analysis as:

> *"a set of methods and techniques that "provides a rich and systematic means of assessing informal networks by mapping and analysing relationships among people, teams, departments or even entire organizations" (p.103).*

Liebowitz (2007) refers to SNA as a suitable technique via which to draw and map the relationships among social agents to examine the strength of their ties. For Freeman (2000), SNA is a multidisciplinary field based on the interdependency of social agents, with ties among them revealing significant characteristics, such as opportunities and constraints.

Sociogram is a term which refers to the graph drawn in SNA. SNA is used for many and varied reasons. It has been used in knowledge management (Kim and Busch, 2016), information systems (Burgess et al., 2016) and marketing (Rocha et al., 2018) among many others.

For the purpose of marketing, Rocha et al. (2018) use SNA in the network of cooperation in the film industry and show that there is a restricted and discrete cooperation in the film industry. Their study is based on the network of connections among producers as well as between distributors and producers in Brazil. The authors conclude that it would be unlikely for the Brazilian film industry to evolve to a broader market scale.

Focusing on knowledge management, Kim and Busch (2016) use a petri net (i.e. an assortment of directed arcs linking places and transitions) in order to investigate the differences between the two views of how employees work and how managers see what employees do at work. They also use SNA to understand the connections among employees as well as the knowledge flow among them. They recommend re-organisation of work processes as well as a change in who is working with whom. Schröpfer et al. (2017) employ SNA to map the flow of knowledge among project teams that were working on a sustainable project in construction. Castro (2007) uses SNA to perform an ethnographic study on indigenous people. Furthermore, Allan (2004) researches the conversations in a discussion forum to investigate who shared what information with whom and when using SNA.

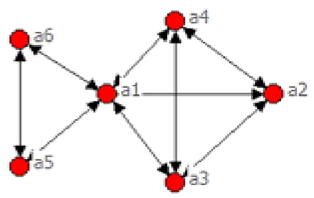
In the field of information systems, Burgess et al.'s (2016) study on literature diversity suggests that the structure of connections between studies is topic-based. The challenge in the information system field is related to the separation/disconnection of studies into business topics and computing topics. Burkhardt and Brass (1990) use SNA to study the organisational effects of a new system for information distribution. They find a change in the structure of the social network after adopting the new system, as well as an increase in the influence power of those who first adopted said system. Zack and McKenney (2000) employ SNA to reveal that prior social structures have impacts on the approach that an entity uses to adopt an e-communication system. Sarbaugh-Thompson and Feldman (1998) relate to SNA to illustrate how the use of an e-communication system reduces the interactions (face-to-face, fax, phone calls) between agents.

2.2.3.1. The Levels and Measures of Analysis in Social Networks

There are three levels of analysis in SNA. The micro level, or ego analysis, refers to individual agents and their ties. The meso level reflects on teams/groups' ties. The macro level relates to organisations or groups of entities, communities and their connections (Borgatti and Foster, 2003). With SNA, several levels can be studied at the same time (Hanneman and Riddle, 2005). Their interconnectedness can also be considered (Marsden, 1990). This means that research on individual social agents might also consider them in the context of their teams (Klein et al., 1994). Even so, the findings in one level might not be found in the next level of analysis. Whilst an entity might have a large amount of information, its divisions might have technological issues, structural problems or communication difficulties and therefore be unable to receive and handle enough information. On the other side, it is also possible that some divisions will have a large amount of information due to having access to specialists or professionals, but information at the organisation level would not be enough and would be handled/assessed poorly (Anand et al., 1998).

According to Wasserman and Faust (1994), each level of analysis in SNA has different characteristics. At the organisation level, density, cohesion and centralisation are the main features of the network. At the team or group level, distance, clusters, and cliques are important. Key characteristics at the individual agent level are agents' similarity, degree centrality, betweenness and closeness. Contractor et al. (2000) explain that SNA has a wide range of measures to offer. These measures have been developed based on mathematical concepts and can uncover important characteristics of the network.

Network Density: Network density represents the number of ties present, compared to the total number of network ties possible (Marsden, 1990). Infographic 1 below shows a network, whilst Table … illustrates the number of connections between agents. Density is calculated accordingly.



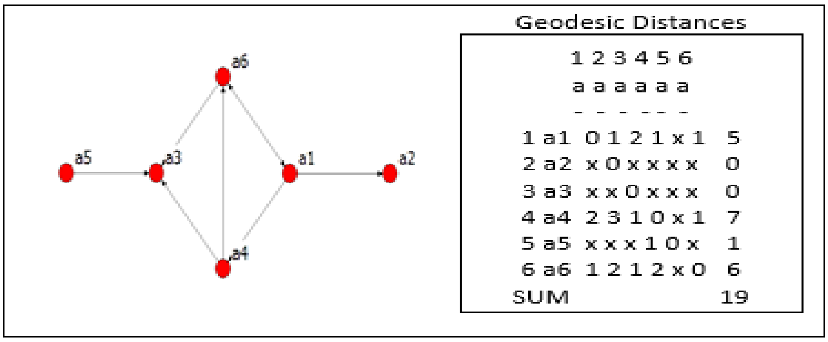
	a1	a2	a3	a4	a5	a6	sum
a1		1	1	1	1	1	5
a2	1		1	1	0	0	3
a3	1	1		1	0	0	3
a4	1	1	1		0	0	3
a5	1	0	0	0		1	2
a6	1	0	0	0	1		2
							18

Infographic 1: Number of connections between agents in a network

The density of the network in Figure 4 is 18 / (6*5) = 18 / 30 = 0.6.

Denser networks have stronger communications among networked agents. Hence, knowledge sharing is expected to increase as the network becomes denser. Allen and Cohen (1969) provide evidence showing that, between different types of interactions, knowledge sharing is highlighted more among agents. In addition, multidisciplinary knowledge sharing occurs among those agents who are central to their fields. This means that denser networks provide a multitude of ties through which access to knowledge becomes easier. Yet, according to Burt (1992), the information that is flowing through ties in denser networks turns out to be dismissed/redundant over time. Instead, there is less knowledge redundancy in the sparse networks, which have many structural holes.

Network Cohesion: Cohesion refers to the extent of interconnectedness (Falci and McNeely, 2009) through the number of ties that exist in the network (Festinger et al., 1950). A walk is related to a sequence of agents and connections, starting and ending with those agents. Cohesion can be measured through geodesic distance. Geodesic distance is the number of connections in the shortest walk (often the most optimal and efficient one) from one agent to another. Infographic 2 shows a network and the geodesic distances among its agents.



Infographic 2: A network and the geodesic distances among its agents

The geodesic distance from a1 to a2 is 1.

The geodesic distance from a1 to a3 is 2.

The geodesic distance from a1 to a4 is 1.

The geodesic distance from a1 to a6 is 1.

No geodesic distance exists from a1 to a5.

There are 13 walks in the network.

The average (mean) geodesic distance among accessible pairs of agents (19/13) is 1.462.

Distance can represent the medium of communication, i.e. face-to-face, phone call, discussions, etc. For instance, Conrath (1973) presents a study in which individuals who are up to 100 feet apart choose the face-to-face method of interaction rather than making a phone call, and the likelihood of such a choice is 22 times higher. In addition, according to Cross et al. (2001), agents tend to have more interaction with those in their immediate locality. In their study, scientists who want some assistance are 5 times more likely to talk to a person vs. searching in a database. Hansen (2002) also shows that agents involved in a project group reach the information they require for finishing their project easier and faster when they refer their need to the local divisions around them.

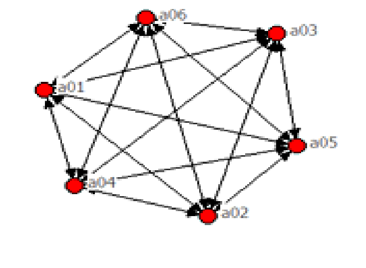
According to Wasserman and Faust (1994, p.249), cohesion refers to “the subsets of actors among whom there are strong, direct, intense, frequent and positive ties”. At the individual agent level, those with the top cohesion scores appear to follow the values, principles and standards of their team and to strengthen its uniformity. Hence, the cohesion of the network or team will be the mean of the cohesion scores of its member agents.

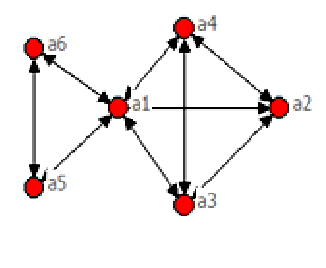
Network Centralisation: Centralisation is another feature of a network. It is a measure at the macro level and shows how centrality has been distributed in the network. In this context, centrality refers to the agent’s network position. Centralisation also highlights the extent of variance in the centrality distribution of the network. In order to find the network centralisation, it is necessary to:

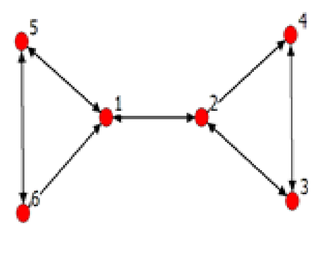
(1) Find the most central agent A*.
(2) Find its score of centrality and subtract from that the centrality score for each of other agents Ai.
(3) Sum up the differences: Σ (A*-Ai).
(4) Divide this summation by what this sum can be if we had the largest possible centralisation: Max Σ (A*-Ai).
(5) multiply the answer by 100 in order to reach the percentage.

Centralisation = 100 * Σ (A*- Ai) / Max Σ (A*-Ai).

Network Blocks, Cut-points and Bridges: Networks are characterised by blocks, cut-points and bridges. A cut-point is a node, and if this mode is removed, the network will break into detached segments. Blocks are the segments or parts that result from cut-points. On the other hand, a bridge is a tie between two agents, and if it is removed the network will break into detached segments or parts. It is evident that cut-points and bridges are illustrative of vulnerability in the network. In fact, the cut-points and bridges can be disruptive to information flow as well as delivery of resources and exercise of influence. Infographic 3 shows these concepts.



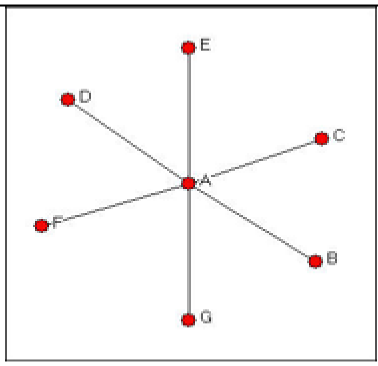
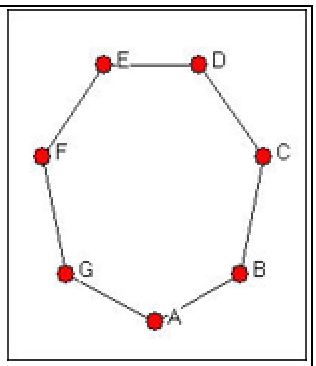




No cut-points. No bridges.	a1 is a cut-point, no bridges. Two blocks: (a5, a6) and (a2, a3, a4).	1 and 2 are cut-points. Tie between 1 and 2 is a bridge.

Infographic 3: Network Blocks, Cut-points and Bridges

Agent’s centrality: According to Wellman et al. (2006), centrality reflects the prominence and position of the agents in the network. Freeman (2000) refers to the evaluation of centrality through degree, betweenness and closeness. Degree centrality represents the number of ties the agent has in the network. Betweenness centrality shows the extent of being between any other two agents. Closeness centrality reveals the separating distance between a particular agent and other agents in a network. Knowledge brokers can be discovered through high betweenness centrality. A knowledge broker is the agent that shares knowledge and information with other agents who do not (Contractor et al., 2000). The direction of an agent's centrality is revealed by out-degree and in-degree centralities and illustrates who shares the knowledge and who receives it, respectively. Infographic 4 presents these concepts illustratively with examples.

Centrality		
Degree Centrality	A has 6 connections. B, C, D, E, F, G have 1 connection.	A B, C, D, E, F, G have 2 connections.
Closeness Centrality	Farness: A gets in 1 step to each of the other 6, 6*1=6 The rest get to A in 1 step and to the other 5 in 2, 1+5*2=11 Closeness: A (1/6) =.167 nCloseness: A 100*(7-1) *1/6=100 The rest 100*(7-1) *1/11=54.545.	Farness: 2*1 + 2*2 + 2*3 = 12 Closeness: 1/12=0.08 nCloseness: 100*(7-1) *1/12=50
Btweenness Centrality	A is in all geodesic paths between any pair of the others. There are 6 others and 6*5/2=15 ways you can get from any of the 6 to any of the other 5, so for A=15. For the rest 0.	All of them are on 3 geodesic paths (e.g. A is between B&G, B&F and C&G).

Infographic 4: Measuring Agent's centrality in a Network

Rulke and Galaskiewicz (2000) use degree centrality and tie intensity to show that both distribution of information in the team and the team's performance are influenced by the team's structure. In addition, social network analysis reveals the common areas. For instance, in the social networks, when the boundaries of the team are defined (e.g. divisions in the organisation, scientific associations, etc.), the team members appear to have homogeneity in their thoughts, knowledge, values and policies. Boland and Tenkasi (1995) call these work teams 'communities of knowing'. Another example is Van Wijk (2003), who refers to differences between knowledge diversity and common knowledge. He explains that the two emerge out of differences which exist between deep knowledge and wide knowledge. Deep knowledge is linked with expert (specialised) knowledge and wide knowledge is related to broad (general) knowledge. According to the above author, knowledge diversity and common knowledge are governed by the depth and extent of knowledge. Social network analysis can facilitate measuring the extent of common knowledge in individuals, teams and the complete organisational network.

2.2.4. Social Network Analysis: Qualitative and Quantitative Methods

According to Heath et al. (2009), social network analysts have used a number of methods in order to capture and evaluate relational data from the qualitative perspective. Anthropologists such as Barnes (1954), whose research project focuses on London families, and Bott (1957), whose study addresses networks of couples and families, have made ethnography a popular method of SNA. Emmel and Clark (2009) employ ethnography to study communities and connected lives. Other researchers use methods such as observation, participants' practice diaries (Seed, 1990), walking interviews, and a technique of visual mapping by participants to generate names (Emmel, 2008). Emmel and Clark (2009) state that visual mapping by participants has the advantage of allowing the participants to "move from description of social practices to their elaboration and theorisation" (p.16). Pahl and Spencer (2004) have used the homocentric circles method, whereby participants would place the names of their contacts in various homocentric rings on a piece of paper, putting the closest in the most central ring. Heath et al. (2009) first use interviews with egos (16 participants) and from there they use interviews with alters (107 participants). Hence, rich data is captured which includes information about alters through the eyes of the egos but also information from alters according to their own perspective. This is different from studies on ego-networks, which use questionnaires to generate names. In the case of Heath et al. (2009), they collect data about families and their experience in education, finding a common understanding and the frameworks of reference as well as potentials and expectations. Therefore, they have been able to identify critical factors in the network for making decisions about education.

It is evident that a variety of visual data, narratives and observations about social networks emerge from qualitative methods. Qualitative social network researchers then analyse the data using content analysis and thematic assessment, as well as by positioning the data on networks within broader contextual research results.

From the quantitative perspective, the prominent method of collecting the data is through name-generator questionnaires. The data confirms whether ties exist among the networked agents. SNA in the quantitative mode reveals the sociogram and measures the structural features of the network (Carrington et al., 2005). Data collection can be achieved through a mass survey similar to what Fischer (1982) carries out to capture personal network data in the state of California. He asks people to write the names of anyone they know with certain questions, e.g. about friendship, giving/receiving support etc. Wellman (1990) in Toronto also uses a similar approach. In addition, it is possible to generate quantitative network data from qualitative methods. In this case, observational data, interviews, documents etc. are used for quantifications of narratives (Edwards and Crossley, 2009) through an adjacency matrix in a spreadsheet in which (1) would represent presence of tie and (0) would show its absence. Ties might be directed or undirected. There exist a variety of software that can help in social network analysis, such as UCINET. Creating the visual map of the network is generally possible after the data collection. However, Hogan et al. (2007) employ visual mapping by participants during their interviews. These maps then turn into a matrix of data to be analysed quantitatively. The matrix of the data can be visualised through a sociogram. It is important to note that the nodes located in the centre of the sociogram do not necessarily have the most centrality among other nodes in the network. In order to find the most central agents in the network, it is necessary to perform structural measurements that are more precise. SNA software can calculate and present the density of the network, node centrality, brokering positions, information flow, etc.

It is possible to measure such structural network analysis, in order to justify the flow of resources, knowledge and ideas in the network as well as to reveal the behaviour of such flow in different types of networks (such as networks with many structural holes, and which are sparse, centralised, and dense). Opportunities and threats to the network and to the agents (based on their positions) can also be identified. Further, advanced analyses would provide varied properties of the network, including dynamic processes that are developed over time (Carrington et al., 2005; de Nooy et al., 2018).

It is pertinent to note that quantitative methods of social network analysis have offered crucial contributions to the network research. These approaches have facilitated the analysis of elements which cannot be easily analysed using qualitative methods. In particular, when the volume of the narrative data is enormous and there is a huge number of relations among agents, then the quantitative SNA using software is very useful, easy and fast. In addition, according to Hanneman and Riddle (2005), since the data matrix helps the researchers to identify the patterns and trends in the data, new research questions can also be designed.

However, whilst the quantitative methods are dominant, the value and effect of qualitative SNA cannot be underestimated. Emirbayer and Goodwin (1994) state that:

> *"Network analysis gains its purchase on social structure only at the considerable cost of losing its conceptual grasp upon culture, agency and process. It provides a useful set of tools for investigating the patterned relationship between historical actors. However, these tools by themselves ultimately fail to make sense of the mechanisms through which relationships are reproduced or reconfigured over time" (pp.1446-7).*

In addition, Crossley (2010) asserts that:

> *"Network structure is not the whole story and for that reason we need to supplement methods of formal network analysis with qualitative observations about what is "going on" within a network" (p.21).*

Reflecting on the arguments above, it is justifiable to use a mixture of qualitative and quantitative methods of SNA. Examples of such attempts are Mische (2003), Crossley (2010) and Kelman et al. (2016).

Having reviewed all of the above, this section (Section 2) put forth a conceptual exploration to present the definitions, concepts, characteristics and typologies of social networks of knowledge. In addition, it highlighted the definitions and scope of social network analysis, as well as its methods (qualitative and quantitative). This comprehensive literature review made it possible to cover the key concepts of the second dimension for this interdisciplinary research (i.e. knowledge sharing and social network analysis).

The next section (Section 3) will focus on the third dimension of this research, which relates to the knowledge sharing and systems thinking approaches. It provides the basic concepts of systems thinking and the developmental journey of the methods. It then focuses on complexity management and justifies the choice of the system model for this research.

2.3. Section 3: Literature Review on Systems Thinking for Knowledge Sharing

The focus of this section revolves around the literature concerning systems thinking, complexity science, and their development. It will first lay out the basic systems concepts. Following this, systems thinking and complexity management will be discussed. Finally, the choice of a systems thinking approach for the complexity management in the process of knowledge sharing will be detailed.

2.3.1. Systems: Basic Concepts and Definitions

This section provides some definitions of the basics of systems concepts. It relates to the notions of system, boundaries and environment. Further definition of the basics for the concept of complexity, such as element-relations, entropy/negentropy, and positive/negative feedback, are explained in later sections. Thus, for this section, let us clarify what is meant by a system, a boundary and the environment.

2.3.1.1. Systems, Boundaries and Environment

While the word "system" has been used very loosely in the literature, this thesis will employ Shaked and Schechter's (2017) definition, which describes a system as:

> *"A functionally related assemblage of interacting, interrelated or interdependent elements forming a complex whole" (p.9).*

For a system to be identifiable/recognisable, it must be bound somehow. A boundary is placed around a system to distinguish the internal and external elements of it and to identify input and output relating to, and emerging from, the system (Ng et al., 2010a, 2010b). The specification of boundary is intrinsic to how we define the elements of the system, how the components interrelate among said elements, and what the goal of the system is (Barile et al., 2012). Von Bertalanffy (1956) states that:

> "*It is necessary to study not only isolated parts in the process; but the essential problems are the organising relations that result from dynamic interaction and make the behaviour of parts different when studied in isolation or within the whole" (p.1).*

To further clarify the concept of boundaries, two issues should be considered. The first issue relates to the "nature" of boundaries. There is a trap of thinking about boundaries as barriers which separate one thing from another. Instead, a boundary should be regarded as something that establishes, creates and forms the bounded. Hence, a boundary will be seen as enabling rather than restricting. As Zeleny (in Boulding and Khalil, 2002) states:

"All social systems, and thus all living systems, create, maintain, and degrade their own boundaries. These boundaries do not separate but intimately connect the system with its environment. They do not have to be just physical or topological, but are primarily functional, behavioural, and communicational. They are not "perimeters" but functional constitutive components of a given system" (p.133).

The second issue refers to where the boundary is "placed". With the tendency of a system's observer towards a visual map of the components of the system, he/she would be inclined to reason in spatial terms. In addition, the prevalence of examples such as biological complex systems reinforces this propensity. However, social systems are not bound in the same way. For example, the components of social systems might exist in different locations. In addition, the relations between a social system's elements might be virtual and hence the system might be in a virtual space. In this arena, Cilliers (2001) draws two key implications:

"The first is that non-contiguous sub-systems could be part of many different systems simultaneously. This would mean that different systems interpenetrate each other. […] A second implication of letting go of a spatial understanding of boundaries would be that in a critically organised system we are never far away from the boundary. If the components of the system are richly interconnected, there will always be a short route from any component to the "outside" of the system. There is thus no safe "inside" of the system, the boundary is folded in […]. Everything is always interacting and interfacing with others and with the environment; the notions of "inside" and "outside" are never simple or uncontested" (p.6).

Moreover, according to Golinelli (2010), boundaries can structurally help in distinguishing between processes of the observed system and processes that are regulated by other systems (in the environment). Such boundaries undertake the function/role of communication between the internal context and the external environments. However, this role or function of a boundary would vanish (Ng, Williams and Neely, 2009) to move from the structural view towards a dynamic perspective (Barile et al., 2012).

In conclusion, it is evident that boundaries of systems can influence an observer's understanding of such systems and affect the way in which he/she deals with systems. One way to appreciate a system's boundaries is through Midgley et al.'s (1998) boundary critique. However, throughout such critique, the enabling nature and positioning/placement of the boundaries need to be recognised. Overall, with the above-mentioned clarifications about the concepts of system, boundary and environment, it is now important to proceed to the next step, which is to explore the idea of systems thinking. Moreover, in order to choose the most suitable systems approach for the processes of collaborative knowledge sharing in a learning context in this research, it is important to discuss the approaches of systems thinking within its developmental journey, and this will be dealt with in the next two sections.

2.3.1.2. Systems Thinking: Common Understanding

The common understanding of what systems thinking stands for is discussed in this section. In very general terms, systems thinking is a way of thinking about a system. With the concepts of systems, boundaries and environment explained in the previous section, it is now easier to relate to the concept of systems thinking. Systems thinking has been defined in various ways by different intellectuals, but all of the existing definitions in the literature share two main features. First, they all see the system beyond its components. Second, they all see the components in the context of the whole. Systems thinking does not attempt to break the phenomenon into its components; instead, it focuses on how these interacting components act and react together, in a network of interrelations and interactions. Systems thinking observes the system as a complex and integrated composition of a variety of interrelated elements which are required to work together in order to enable the whole to successfully function (Shaked and Schechter, 2017). A systems thinking approach is considered a counter-approach to non-systemic methodologies, which think of and act upon things as if they were mere aggregates of parts. For example, classical mechanistic management theories focus more on components of a phenomenon and attempt to separate the elements in order to analyse and understand each of them individually. According to Ackoff (1997), the mechanistic approach declares that we should apply objective and value-free empirical testing of universal laws to analyse, understand and describe the whole as a reassembly and aggregate of the simplest components (Churchman, 1979; Boulding, 1956; von Bertalanffy, 1968). On the other hand, the systems approach was offered as a way to study and act under the holistic premise in which the whole transcends the sum of its parts. The anti-reductionist and anti-analytic argument of the systems approach could be summarised as to isolate a phenomenon from its context (reductionism) and begin its study by a separation of its parts (a-priori analysis), means losing sight of the holistic condition of any phenomenon.

Having reached this common understanding of systems thinking, the next section provides the literature on complexity management.

2.3.2. Systems Thinking: Complexity Management

In order to understand the ways in which complexity can be managed and dealt with, it is necessary to first clarify what the complexity is. This section also provides the literature around the notion of complexity and its basic concepts.

2.3.2.1. Complexity: Definition and Basic Concepts

Complexity is a feature of the world so prevalent and intuitive, yet so perplexing as to have a myriad of conceptions across the physical and social sciences. The Oxford English Dictionary (2nd ed. 1989) defines complexity generally as “composite nature or structure”, or “intricacy”. Specific to mathematics, it has been defined as “a measure of the difficulty of solving a class of problem, … the expected number of computational steps”. In science and engineering, complexity theory refers to the “mathematical study of nonlinear dynamic systems… [which] often follow power law distributions” (Farber, 2003).

According to Beer (1966), a high level of complexity emerges in the systems that are capable of proliferating a high variety of the system’s states. The states of the system, in this arena, refer to its configuration (pp.250-252). The variety of configurations is therefore a measure of complexity. It is important to emphasise that variety is about a system’s states and not a system’s components. This is because if we interpret variety as the number of a system’s elements, it would mean that the system is just a collection of components. The variety of a system’s configurations increases considerably when the number of its components and the states of those components increase. With variety being the number of possible states of a system, in order to manage the complexity, Ashby’s (1956) law states that “only variety can destroy variety” (p.207). According to Abdelkafi (2008), the first variety in Ashby’s law relates to the diversity of a system’s configurations/states and the second variety in his law refers to the diversity of the environment’s states (pp.71-72). What Ashby’s law says is that only when the system’s variety matches the environmental variety can we say that the system has ‘requisite variety’. In general, complexity refers to “elaborate temporal and spatial patterns and structures… [that] are hard to describe, explain, or predict” (p.2011).

In a social context, complexity is “the number and diversity of players who are involved in a project. The more parties involved in a collaboration, the more socially complex” (Conklin, 2006). Complex organisational systems are distinguished by (a) increased scale, or number of functional units, (b) increased differentiation, or number of units devoted to different tasks or technologies, and (c) increased interdependencies, or the number of units coupled in authority-based, resource-based, or norm-based relationships (LaPorte, 2015). Complexity is a structural variable that characterises both organisations and their environments. Natural and social systems tend to exist in one of three states: simple, complicated, and complex. Dekker, Cilliers and Hofmeyr (2011) describe the difference between complex and complicated, noting: “Certain systems may be quite intricate and consist of a huge number of parts… Nevertheless, it can be taken apart and put together again. Even if such a system cannot practically be understood completely by a single person, it is understandable and describable in principle. This makes them complicated. Complex systems, on the other hand, come to be in the interaction of the components… [and are] held together by local relationships only. Each component is ignorant of the behaviour of the system as a whole, and cannot know the full influences of its actions" (p.942).

To date, systems thinking has been particularly facilitative in managing complexity (Carson and Flood, 1988). Here is where issues can be 'messy'. Messy problems (coined by Ackoff) are more complex than simple and complicated issues. Ackoff (1974) reveals that complex problems are messes. He mentions that:

> *"Every problem interacts with other problems and is therefore part of a set of interrelated problems, a system of problems. […] I choose to call such a system a mess" (p.21).*

Messy problems are recognised for their long-term implications, more interrelated elements, more individuals, and higher uncertainty level (Reynolds and Holwell, 2010). Similarly, the situation and issues in this research can be considered as messy. The researcher diagnoses and uncovers a network of problems which is discussed in detail in Chapter 4. Hancock (2010) suggests dealing with messy problems through resolving their complexity rather than solving them.

Complexity can also be understood in terms of the capacity of a system to assume and retain "a large diversity of states or modes of behaviour" (Schwaninger, 2009). A system which only possess one or a few unchanging elements would be relatively simple and describable, and generally predictable. The complexity results from the increasing connectedness of the human world: "whether it works for us or against us depends to a large extent on the amount of diversity" (p.2011). Diversity can be expressed in three ways: (a) variation within a type, (b) differences between communities or systems, and (c) differences across types. The first conception refers to variation, in the statistical sense, of a single parameter across a range. The second conception refers to compositional differences between systems, such that the components/elements are the same, but their number and interaction can differ. The final conception, differences across types, refers to a characteristic that can appear in multiple forms despite potential functional differences (p.2011).

2.3.2.1.1. Complexity: Element-Relations

Complexity is not only governed by the amount of differentiation, but also by the nature of the relationship between individual parts. According to Bush, Martelli and Roberts (2012), some authors draw a distinction between component complexity (i.e. the raw number of potential interactions between units dependent on one another), and combinatorial complexity (i.e. the number of system interactions, including feedback loops and partially or completely delayed effects from decisions). Others argue that complicatedness is not a feature of the system per se, but relative to the management of a complex system – whereas complexity is "an inherent property of systems…, [complicatedness] is a derived property that characterises the ability of an execution unit to manage a complex system" (Tang and Saliminen, 2001).

In the context of uncertainty, as the number of multiple relationships between units of a system increases, it becomes more difficult to adequately describe the nature of these relationships and, in turn, more difficult to describe and manage the system. This is because complexity results in dynamic tasks that require highly interdependent coordination, indeterministic processes, and sub-systems with decentralised control. In situations of complexity, outcomes cannot be predicted with any certainty. The hallmarks of uncertainty are indeterminism and incomprehensibility. These hallmarks are caused by the complexity of the external environment of an organisation. As the level of complexity increases, the ability to measure, comprehend and plan decreases. Beer (1966) expresses that "The measurement of complexity in terms of variety specifies also a measurement of complexity in terms of uncertainty" (p.258). According to him, uncertainty is removed through provision of information (p.250).

2.3.2.1.2. Complexity: Entropy/Negentropy

A manifestation of a system's uncertainty and disorder is called entropy, whereby the system becomes formless and unconnected. It represents lack of information/energy and incapability to lead the change in the system towards an order (Swanson and Bailey, 2009). A closed system, such as a machine which does not receive any energy from outside, has a tendency to lose its maximum energy and become maximum entropic. Based on information theory, entropy means loss of information in a communicated message. Hence, with every transmitted message there is a measure of it which is lost. Disorganisation in the system is then the consequence of an increase in inevitable entropy. According to Brillouin (1953), negentropy is the availability of high-quality energy. When a system features differences, it contains more negentropy. An open system can demonstrate negentropic propensities through which order in the system is increased and sustained. Since negentropy represents order and patterns in the system, it resembles certainty and a move towards an organised state. According to Ashby (1956), the order in a system means more structural couplings and connectedness among elements. Hence, open systems can orderly differentiate themselves through increasing their complexity.

Negentropy is what makes a structure a structure. A structure is a storage of pulled out negentropy. Based on the second law of thermodynamics, negentropy can, however, be dissipated as a conversion into entropy. Negentropy cannot emerge from entropy. It must be imported from an existing source that is negentropic itself. A system can only be rescued from a disordered state and placed into an ordered state if it is an open system and high-quality energy is added. With the flow of negentropy into a system, entropy will be displaced to somewhere else. To explain where the somewhere else is, it is important to state that, since all of the realities are structured, with the displacement of entropy of system x into its environment (which helps the system to maintain itself), entropy is discharged from system x to another system (y). In this scenario, system x makes others pay a double price in order to preserve itself. First, system x imports negentropic resources from other systems (y), and also discharges its entropy as waste to them. Without this, the entropy would accumulate within system x, which means an increase in the dissociation and decay in the connective structure of system x. This can lead system x to breakdown (Boulding, 1977).

The question of how entropy and negentropy (discharge and charge of energy or information) impact the preservation of the system is important. This question is effectively answered by considering systems' feedback loop mechanisms as follows.

2.3.2.1.3. Complexity: Positive/Negative Feedback

Feedback loops are of two types, namely positive and negative. All systems, regardless of degree of complexity, are directed by positive and negative feedback loops, based on which the dynamic of the system emerges. This process involves observing the behaviour of the system and feeding the specific indicators back to its sensory mediums. For example, a UK firm producing soft drinks may observe a high level of diabetes in the environment. It might also find that the NHS promotes low-sugar drinks. The firm might conclude that its high-sugar soft drinks may have contributed to such disease. In addition, the firm might foresee sugar-tax on soft drinks. These observations feed the relevant information back to the firm in order to assess the impact on corporate image, as well as on sales/profitability. This information is analysed in the firm, e.g. for making decisions regarding developing new soft drinks that contain less sugar. Hence, positive and negative feedback loops influence the overall behaviour of the system. According to Nichols (1996), feedback loops which bring information and other forms of input into the system operate so as to promote stability and change in the system. When a system becomes too complex, it needs self-regulation. According to Clemson (1984), a feedback loop is the mechanism for self-regulation through "circular casual processes" (p.22). It is important to understand that self-regulation happens both in the system and in its environment. A degree of stability in the system is generated through its self-regulation. A very complex probabilistic system can regulate itself, to some extent. The predictability of the results of managerial activities is dependent on understanding how a system regulates itself.

The simplest feedback structure emerges when there are only two components and they constantly interact with each other in such a way that the outcome of one regulates the next action/behaviour of the second component. A negative feedback in this process relates to goal seeking. Based on said feedback, the system resists the disruptions that cause it to depart from/abandon its goal. This means that the response of one component is to constrain the change in the other. A thermostatic control for an air conditioning system is an example: the thermostat switches the system on and off so as to preserve a specified temperature. The design of this operating system guarantees stability (the room's temperature is kept within a specified range). However, since this is a first-order feedback system, the goal of the system is specified externally. On the other hand, positive feedback refers to the deviation of one component from its current state, which causes the amplification of the behaviour of the second component. Positive feedback systems, whilst unstable, can be useful. For example, as Beer (1959) explains, the power-assisted braking system amplifies the small act of moving the brake pedal "until the force applied is capable of stopping a vehicle in motion" (p.31). In contrast, a second-order feedback system is able to select from a number of possible responses to the changes in the environment, in order to reach its goal. A third-order feedback system goes further to allow the system to change its goal itself and internally as a response to feedback processes (Beckford, 1993).

Feedback systems in organisations are very complex, since they have many elements connected in numerous different ways, and these connections can create both positive and negative feedback loops. In addition, it is likely that, at any time, the "sum" of the feedback loops might work in a positive or negative way (Beckford, 1993). Clemson (1984) explains the impact of failure or success on the action of a sports team:

> *"Given two teams that are roughly evenly matched, if one team plays very well and begins to pull slightly ahead, the other team is stimulated to greater effort and tends to catch up, i.e. the two function as a negative loop in minimising the score difference between them. However, suppose one team is having a horrible night and gets completely demoralised in the first ten minutes. As the game goes on and they get more and more hopelessly behind they will tend to play less and less well and the better team will relax and everything will go right for them.*

In this case, the two teams are functioning so that the overall feedback loop is positive in maximising the score difference" (p.23).

In due course, it is possible that big changes in that behaviour could emerge because of trivial changes in the internal connections/relationships. Hence, the systems that consist of feedback loops have the capacity to demonstrate extremely complex behaviour.

According to Beer (1959), there are two important aspects that arise from the negative feedback. First, given that the feedback mechanism does not break, the system will not go out of control, because in the process of regulation it will correct itself. Second, the effectiveness of the system is guaranteed against any type of trouble or disturbance. In order for a feedback system to be effective, a number of design conditions are required: (1) all components of the system must be properly working and there must be adequate communication channels among them; (2) There must be clear allocation of tasks, roles and responsibilities; (3) The controls and regulations must be selective; and (4) The necessary actions must be highlighted by the control/regulatory mechanism (p.29). Through this design of feedback mechanisms and the relevant channels, negentropy (energy and information) comes from the environment, transforms the behaviour of the system’s components and affects the self-regulation and the preservation of the system, putting entropy at the bay.

Having clarified the notions of complexity, element-relations, and entropy/negentropy as well as positive/negative feedback, we can now proceed with understanding the management of complexity.

According to von Hayek (1972), the theory of complexity is called cybernetics, and Beer (1972) refers to cybernetics as “the science of effective organisation”. Wiener (1965) defines cybernetics as “the science of communication and control in the animal and the machine”.

In order to manage the complexities of a system, we attempt to model that system. However, what we create/build as the model of the system is simplified. The resultant simplified models essentially do not consider those facets of the system that are unrelated to the objectives for which a system’s model is built. Since the properties of a model depend on the model creator, the system’s characteristics would also be differentiated from the properties and features of its model (Heylighen and Joslyn, 2001). However, the distinction between a system and its model for an engineer who works in a mechanical framework is far less important. He/she knows the system’s internal structure and its behaviour with a high level of accuracy and therefore acts as “if the model was the system”. Such an engineer looks at the system with the view that the system is objective, and can be easily observed and controlled. Yet, not all systems are like engineering systems. Hence, the system/model distinction refers to the level and extent of efforts of the second order cyberneticians who study a social system or an organism and realise that said system is in interaction with its observer. Perceiving the case from a quantum mechanics perspective, there is no separation between the observer of the system and the observed system. The outcome of the observation is therefore linked to the nature of interactions between the two. In addition, according to Ashby (1962), "organization is partly in the eye of the beholder" (p.106). Hence, according to Demetis and Lee (2019), the model of the system is observer-relative.

For the purpose of complexity management, any system would be studied based on the balance between the identified input/output feedback loops and in accordance with the purpose that is recognised by the observer (Espinosa and Walker, 2017). This balance can be explained through the concepts of negentropy, feedback loop and organisation. The feedback loops act in a circular way and therefore are self-referential mechanisms of a system. In such circular loops, conditions and outcomes are not isolated. They mutually transform each other in a continuous process of interactions between inputs and performance. This transformation enables the elements of the system to evolve (Bateson, 1958). More importantly, such feedback processes function purposefully to link the conditions and outcomes in a non-stop circulation of negentropy (energy and information) from the environment. The energy and information which are circulated/communicated enable the collaborative oscillation between the targeted performance of the system and its behaviour. With the flow of negentropy from the environment into a system, entropy is displaced to somewhere else. Such complex engagement/interaction is a way in which a system becomes empowered to develop its capacity in order to adapt, self-organise, and increase its complexity. The development of such capacity is vital to the self-organisation and self-maintenance of the system. This means that the system stabilises its existence towards its identity. Hence, the organisation of the system moves far away from disorder through structural embodiment of its purpose and intention (Maruyama, 1960; Bale, 1995).

Having argued the above, with the observer's involvement in the dynamics of interactions among feedback loops and the way they create a stable balance in the system towards its pre-defined identity, the observer becomes part of the system's dynamic and adds another dimension to the multiplex of the behaviour. The observer can be considered as a system that strives to make sense of, build a model of, and attempt to change, another system. How distinct a system is from its model reflects the efforts that a second-order observer makes to study the system in focus or the organism under investigation. Since there is interaction between the observer and the observed, and the outcome of the observation is linked to the nature of interaction between the two, they cannot be totally separated from each other. According to Ashby (1962), "organization is partly in the eye of the beholder" (p.106). The system under investigation is studied based on the balance between the closed feedback (input/output) loops that are recognised by the observer, in accordance with the purpose of the system (Espinosa and Walker, 2017). In this vein, whilst "the purpose of the system is what it does" (Beer, 2002, p.218), making sense of and understanding the purpose of the system is relational. It results from the dynamic of interactions/relationships between the systems and the observer. When an observer studies a system, the value, relevance and likelihood of all behaviours and their combinations in the system are defined by him/her and are relative to his/her level of observation. The observer's role and his/her judgements bring to light the subjectivity of emergent knowledge about the system and its purpose. This is in agreement with Ashby (1961), who reveals that the purpose of the system can become paradoxical, since it is not necessarily a feature of the system itself but is a specification that can be meddled with by the observer. Therefore, the observer's inference about the system is important in the success or failure of the system, because the subjectivity of his/her knowledge plays a key role. Here, there are two points. First, it is important for the observer to have developed an accurate model of the system based on deep understanding of the system's feedback loops and systems dynamics as well as the system's boundaries. The second point relates to the observer's accurate recognition of the system's identity, purpose, current performance and state of order, as well as his/her own ability to concurrently learn about and manage the complexities of the system. Given that it is not possible for the observer of social systems to be fully objective, any interaction with the system may potentially change the system, and consequently also change the observer's perception.

In this vein in fact, the observer is considered as a cybernetic system that strives to make sense of, build a model of, and attempt to change, another cybernetic system. This process is called "cybernetics of cybernetics", or second order cybernetics, and results in the development of a meta-language in analysing and explaining the behaviour of the system in focus. This meta-language facilitates our understanding of the complexities that arise from the networks of relationships in the system. For example, Ashby (1962) coins the term "variety" as a measure by which complexity can be perceived (p.106). Ashby (1964) explains that the complexity of a system can be considered as that system's potential to reveal various states or behaviours which are out of its dynamic network of relationships. Another example is self-organising dynamic systems. Such a system begins with its separate components. The behaviour of each component is independent from the behaviour of other components. These components then interact with each other. Some types of connections are shaped and, as a consequence, the behaviours of the components change. Ashby (1964) elucidates that any isolated dynamic system that follows unchanging rules will assemble organisms that are self-organised and that adapt to their environment. Therefore, within the network of relationships and connections in the system, self-organisation means collective behaviours which surface spontaneously from local relationships. This explains both McCulloch's (1956) work on dynamism in neural systems and Ashby's (1962, 1964) work on control systems, in determining the minimum conditions under which meaning can arise.

In dealing with the complexities of a system, Ashby's law of requisite variety explains that if a system strives to control another system, the varieties of the controlling system have to be at least as great as the varieties of the controlled system. Developing Ashby's law of requisite variety further in the field of management and organisational studies, Beer (1972) recognises the notion of complexity as the nucleus for cybernetic discourse and constructs a generic model of viability for complexity management in social and organisational systems (Beer, 1972), which is well-known as organisational cybernetics (Jackson, 2003). According to Espinosa and Walker (2017), when perceiving systems' complexity through Ashby's concept of variety, it is observed that the range of potential states or behaviours in dynamic social systems is fuzzier, indistinct, less predictable and requires more interpretations than in mechanical or physical systems. Beer's model of viability, i.e. the viable system model, places emphasis on applications in social systems. This model was developed to meet several laws of management, empowering said model to offer criteria for designing organisational systems as well as diagnosing structural issues (Beer, 1972, 1979, 1985).

Central in organisational cybernetics is the concept of self-organisation in business organisations and social systems. Organisational cybernetics features autonomous operations of the system and co-evolution through interactions at local level and shifting from disorder to order (Arevalo and Espinosa, 2015).

Apart from Beer's viable system model, in the mid-1980s there also emerged, from the Santa Fe Institute, another approach of complexity management for autonomously operating systems. This is the so-called complex adaptive system (CAS), which makes it possible to study complex natural and artificial systems. The viable system model and complex adaptive system are commonly used in recognising general features of complex systems across conventional disciplinary limits. The complex adaptive system provides a holistic perspective which relies on self-organisation, path-dependence and learning (Dooley, 1997). However, complex adaptive systems place emphasis on less organised or less integrated systems such as markets and ecosystems, compared to traditional systems such as organisms and organisations (Chan, 2001). In contrast with viable systems, the complex adaptive systems are more of use for understanding and portraying the system through computational simulations and are less useful for problem solving actions and the implementation of a systemic change agenda.

Social systems, according to Buckley (1976), can be studied from the complex adaptive perspective, since they are the most adaptive and most demanding and persistent systems, as well as fitting the principles. He then reveals that cybernetics can be regarded as the language which best facilitates our understanding, whilst also describing the mechanics and structure of the complex adaptive systems. This is in agreement with Beer (1966) and emphasises that control processes involved in physiological and socio-cultural systems share the same cybernetics laws for information flow within feedback loops. Organisational studies have therefore begun to use the complex adaptive perspective as an interpretive framework in order to describe and explain the complex behaviour of organisations and communities (e.g. Carapiet and Harris, 2005; Mitleton-Kelly, 2003).

Another intrinsic specification of the complex adaptive system relates to the concept of open systems. The complex adaptive perspective perceives the systems as “open”, in that, according to Espinosa and Walker (2017), a living system, for example, interacts with the environment, and co-evolves in it through mutual exchange of information and potentials. When we explain the complexities involved in these dynamic interactions, the system is observed from the complex adaptive perspective. The same complex system can be observed from a cybernetic perspective through considering the system as “organisationally closed”. Although the system is open to freely receive information and energy and to co-evolve with its environment, the system is closed organisationally through being self-referential, self-regulated and self-organised.

It is evident that the co-evolution of the system can be explained via the complex adaptive perspective and the complexity management can be explained by organisational cybernetics, i.e. the viable system model. It is observed that complex adaptive systems and viable systems do complement each other in terms of structure and behaviour. According to Espinosa and Walker (2017, 2013) and Allen et al. (2011), these approaches appear to provide firms with holistic foundations to study organisations in managing their complexities. While the ontology of classic science relates to isolated entities, the ontology of complex systems' approaches, such as the viable system and the complex adaptive system, refers to linked entities, embodying a network of connections that can change, with nodes that can adjust internally and capabilities and potentials that can be developed through time. Therefore, new insights into the world as well as new methods for generating knowledge about the world's phenomena are on offer through these approaches.

While the discussions and debates in this section provide some clarifications about the foundation, rationale, logic and methods of complexity management, it is important to analyse some of the systems thinking approaches mentioned in Section 2.3.1 which have potential for managing complexities. Said approaches are those which are found most relevant to this research, the focus of which is the process of collaborative knowledge sharing in a learning context. Carrying out such analysis in the next section will provide a firm justification as to why a particular approach/model/method has been used and deemed to be the most suitable.

2.3.3. The Choice of a System Model for this Research

Reflecting on the theories of systems thinking (See appendix 0) and their relevance to the topic, scope and context of this thesis, the researcher discusses, in this section, the justification of why a second-order cybernetic approach (the viable system model – VSM) has been selected. In this arena, it is important to consider the purpose of the present action/operational research, i.e. to facilitate the development of skills and capability and the improvement of the learning performance through the process of collaborative knowledge sharing and learning. As discussed in the introduction chapter, this thesis revolves around a call for a solution specific to this purpose.

In this section, certain criteria are considered based on the significance of the context, scope and purpose of the research, when evaluating and choosing the approach/model. For instance, quantitative models such as data envelopment analysis (DEA) were rejected because this research has adopted an inductive and qualitative approach. From the perspective of problem structuring, four approaches were selected to be compared for their suitability in this research. (1) Soft System Methodology (SSM): this approach promotes learning and advocates participation as a heuristic instrument for delving into the study of the complexities of real-life problems. This could potentially help in collaborative learning in the present research. (2) Strategic Option Development and Analysis (SODA): this approach develops the cognitive mapping to capture interconnected causal maps and to build a model of the messy problems. It was likely that said approach could help in clarifying the interconnections among the issues and problems in the real-life case study of this research. (3) Viable System Model (VSM): this purpose-orientated approach relates to flow of information in the system, which could directly guide the knowledge sharing among individuals and promote collaborative learning towards skills development, which is the goal of this research. (4) Strategic Choice Approach (SCA): this approach is a means of enabling communication and interactions among those who are responsible for decision making in the system. It refers to the use of technology as a flexible resource which can be employed based on the goal of the users. In the context of knowledge management, this could mean that investing in IT and technology can transform any organisational system into an organisation that is knowledge-based.

In order to evaluate these approaches, the researcher adapted Smith and Shaw's (2018) four pillars of assessment, namely system characteristics, engagement of stakeholders, values of model building and structured analysis. It is important to note that smith and Shaw built these pillars based on Guba and Lincoln's (1989, 1994, 2005) four constructs of ontology, epistemology, axiology and methodology. Mingers (2003) uses three of them for action and operational research and states that they are the most general features which action research approaches have in common. Table 5 shows the connection among theoretical meaning from Guba and Lincoln, operationalisation from Mingers, and Smith and Shaw's four pillars of assessment.

Theoretical construct	Theoretical Meaning (Guba and Lincoln, 2005)	Operationalized construct (Mingers, 2003)	The pillars of assessment (Smith and Shaw, 2018)
Ontology	What we know?	What is included in the model?	**System Characteristics**
Epistemology	How we know what we know?	How is knowledge created?	**Engagement of stakeholders**
Axiology	What is the value of problems solving?	How to evaluate the value of the problems solving?	**Values of model building**
Research Methodology	How to structure the research?		**Structured analysis**

Table 5: Connections among Constructs for Theoretical Meaning, Operationalisation and Pillars of Assessment (adopted from Smith and Shaw (2018))

2.3.3.1. The Four Pillars of Assessment

In this section, the four pillars of assessment and the criteria related to each will be provided.

2.3.3.1.1. System Characteristics

The system characteristics of an approach refer to three criteria. First, operational research approaches strive to build models of the systems under investigation. The model of a system reflects the interlinked components of that system. The components which are included in a model suggest the ontological assumptions of the modelling approach. Hence, the first criterion is whether the approach is able to identify a system to model (criterion 1). Secondly, operational research approaches are designed to aid in understanding the system based on the modelling. According to Ackermann (2012), the focus should be on complexity management rather than on reducing the complexity. This should be achieved through looking at the whole picture rather than the constituent components of the system. Therefore, the second criterion is whether the approach is able to construct/establish a holistic comprehension of the system (criterion 2). Thirdly, according to Franco and Montibeller (2010), there are two perspectives on issues and problems in the systems. On the one hand, traditional approaches assume that issues exist as external realities. On the other hand, in systems approaches, the participants need to build their own understandings of the reality. This allows multiple kinds of subjective knowledge and understanding about the external world to be used in the system modelling (White, 2009). According to Mingers (1993), the system modelling approach relates to participants' subjective understanding of the world (e.g. beliefs and concepts), and moves away from objective modelling. Hence, the third criterion is whether participants' subjective interpretations/understanding are modelled by the modelling approach (criterion 3). Fourth, there are two ways to construct a model of the system. It can be created by an expert or by a facilitator (Franco and Montibeller, 2010). The expert OR consultant is given the information about the problem situation in the organisation and he/she builds a model of the organisational system to provide an optimal response to the issues. Alternatively, the facilitator builds a model jointly with participation via interactions and engagements in group workshops. For Checkland and Winter (2006) there can be two methods of facilitation. The first is mode 1, which is formal team/group facilitation and the facilitator is the expert on the process, supporting the emergence of participants' understanding and knowledge when applying the approach (Phillips and Phillips, 1993). Alternatively, in mode 2, one of the participants uses the principles of the approach and assembles the thinking of the group. According to Johnson and Johnson (2002), between mode 1 and mode 2 is self-facilitation using prompts in a pre-defined process. This helps the group to direct themselves. Hence, the fourth criterion is whether building a model includes facilitations of partakers/participants (criterion 4).

2.3.3.1.2. Engagement of Stakeholders

Engagement of stakeholders relates to two criteria. First, operational research tools and techniques use the model of the system to construct and epitomise the knowledge about the issues/concerns of the system. According to Ackermann (2012), a problem structuring model is of qualitative form and often involves diagrams. Therefore, the first criterion in this section is whether the approach can establish a qualitative archetype/model of the system (criterion 5). Second, based on the discussion regarding criterion 4, the shared understanding/clarity which emerged from facilitation of participants reflects a shared model of the system, advocating a shared language, a common understanding about the situation, and a shared interest (Franco, 2013). Therefore, the understanding that emerges from this exploration is on the basis of transition to concepts clarity, roles, tasks, etc. collectively or individually (Eden and Ackermann, 2006). Hence, the second criterion is whether the approach is able to advance participants' learning about the situation (criterion 6). Thirdly, operational research relates to real actions that are carried out. It is required that these actions be culturally viable and systematically indispensable (Pidd, 2009). Therefore, the modelling approach needs to be equipped with a good set of activities/actions that would change the situation for the better. The actions also need to be politically possible and practically implementable instead of being optimal solutions that might not become operationalised (Checkland, 1981). If political aspects are not considered, then the optimal resolutions can never be implemented. According to Eden and Ackerman (1998), acknowledgement of power structure can help in reaching buy-in from key stakeholders/participants. This therefore justifies the political feasibility of actions. Hence, the third criterion is whether the aim of the modelling approach is in line with the development of agreements and buy-in for the solutions/results that are politically feasible (criterion 7).

2.3.3.1.3. Value of Model Building

Value of model building refers to the axiological assumptions of an approach. First, according to Smith and Shaw (2018), the approach that is used for model building should be generic enough. Such an approach could be used for a variety of issues and different organisations. It should not be restricted to a single context or setting. Therefore, the first criterion in this section is whether the model building approach is appropriately generic to be used in multiple contexts (criterion 8). Second, specific to the research about knowledge sharing in this study, communication and social interactions play an important role in the flow of knowledge and information as well as in collective exploration regarding the complexity of the issues. Therefore, the second criterion is whether the approach is able to model information flow (criterion 9). Third, for this research, the approach towards model building, which is required for the participative solutions, needs to recognise, model and design the joint efforts and collaborative roles in the system. Hence, the third criterion is whether the model building approach is capable of modelling, designing or redesigning the joint task undertakings and collaborations in detail (criterion 10).

2.3.3.1.4. Structured Analysis

The methodological basis of an operational research approach relates to the structures that it uses to analyse a system's model as well as to create knowledge. These can be different methods, tools and techniques. Hence, the first criterion in this section is whether the model building approach can provide detailed analysis of the system's components (criterion 11). In addition, for this research, which focuses on the process of skills development and performance improvement, the approach taken needs to measure and be able to manage the performance. Therefore, the second criterion is whether the model building approach is capable of measuring and managing the performance of the system (criterion 12). Devising these 12 criteria helps in testing which of the four approaches is most suitable for this research. The following sets out the analysis of these approaches for each criterion.

Criterion 1 – Being able to identify a system to model: According to Checkland and Scholes (1990), human activities can be modelled as a system. For SODA, it is the construction of cognitive maps of individuals that illustrates the approach by which an individual defines/describes an issue (Eden and Ackermann, 2001). In VSM, there are five sub-systems with interlinks among them which represent and justify how the organisation functions and remains viable over time (Beer, 1981). For SCA, a number of models are constructed to show the interconnections among different decisions with an objective of decreasing uncertainty (Friend, 2010).

Criterion 2 – Being able to establish a holistic comprehension of the system: A holistic understanding of the system is represented through studying the whole prior to investigations about elements of the system in all four modelling approaches of SSM, SODA, SCA and VSM.

Criterion 3 – Being able to model participants' subjective interpretations and understanding: SSM develops the system of human activities. This system is a goal-orientated and purposeful system. The model of said system is built from different perspectives. Therefore, the resultant resolutions are subjective to the participants' knowledge (Checkland, 1981). For SODA, according to Eden (1995), the model of the system is built from “different subjective views of the situation as expressed through individual interviews” (p.304). Similarly, models developed through SCA illustrate the subjectivity of information (Friend and Hickling, 2005). For VSM, according to Harwood (2019), second order cybernetics distinguishes VSM as a model that enables the articulations of participants’ views and perceptions about how the organisation functions. In this regard, Beer (1985) emphasises that “you are not determining absolute facts: you are establishing conventions ... a model is neither true nor false: it is more or less useful” (p.2).

Criterion 4 – To build the model of the system based on facilitation of participants: Stakeholders’ facilitation in SSM can be through mode 1 facilitation and mode 2 facilitation (Checkland and Scholes, 1990). Similarly, mode 1 and mode 2 of participants’ facilitation are used in the VSM approach to modelling the systems (e.g. Cardoso, 2011; Espinosa and Walker, 2013). SODA follows the same (e.g. Eden and Ackerman, 1998). The SCA approach relates typically to mode 1 of participants’ facilitations (e.g. Franco, 2006).

Criterion 5 – Being able to build a qualitative model: All of the four modelling approaches discussed in this assessment, i.e. SSM, SODA, SCA and VSM, do form/establish qualitative models.

Criterion 6 – Being able to advance participants’ learning about the situation: For SSM, this is achieved through motivating stakeholders/participants to explain and elaborate on their varied perspectives during the process of modelling. This, according to Checkland (1985), facilitates the process of learning. For SODA, learning enhancement is through knowledge sharing and establishing the group’s cognitive maps. For SCA, according to Friend and Hickling (1998), the team should accept open technology in such a way that many participants can share information. This allows them to be participative, interactive and hence their learning is improved. For VSM, despite Jackson’s (2003) criticism of the model as being a mechanistic approach, it is important to emphasise that VSM is based on the cybernetics principles of feedback and control/self-regulation. The control/self-regulation principle is indeed an effective mechanism of learning. Espinosa and Walker’s (2011) work is a good example of this. In addition, Star and Griesmer (1989), as well as Harwood (2009), use VSM as a boundary object. This makes it possible to gauge participants views about what is happening as well as the issues to be shared, and hence learning about the situation is advanced. As such, VSM can improve participants’ learning about the issues and situations, as well as about how an organisation can function.

Criterion 7 – Being able to aim for politically-viable outcomes: In order to establish the buy-in and advance the political viability of the solutions, operation research approaches encourage participation of stakeholders and deal with power issues in the area of concern. For SSM, this is achieved through involving stakeholders and constructing models with them within the process of intervention. For SODA, it is achieved via the creation of a shared understanding in relation to the problem at hand as well as establishing the joint group map, which is either a combination of cognitive maps of individuals or a sole map created by some of the participants.

Eden and Ackermann (1998) state that both "can provide a means of enabling group members to jointly understand the perspectives of others, reflect on the emergent issues that are surfaced from them and begin to negotiate an agreed strategic direction" (p.73). For SCA, shared models are built to promote understanding about the conditions, circumstances and situations. For instance, decision charts signify the connections between various decision zones. Such linkages are the focus for the group. The compatibility net then illustrates the different options available (Friend, 2001). VSM also aims to enhance the buy-in agreement towards politically-viable results, otherwise planned change would not materialise due to resistance of opposition and discouragement by rebels (Harwood, 2019).

Criterion 8 – Being a generic model to be used in multiple contexts: All four modelling approaches have been effectively used in many and varied contexts and situations. Checkland and Sholes (1990) present the case studies of SSM. With regard to the SODA cases, Eden and Ackermann (1998) illustrate these. SCA cases have been highlighted by Friend and Hickling (1998). Moreover, VSM has been used in a variety of situations (Beer, 1981).

Criterion 9 – Being able to model information flow: SSM, SODA and SCA do not relate to modelling information flow. However, VSM is able to model how information flows throughout the communication channels (Flood and Jackson, 1991, p.92). It highlights both existing and missing links in different communication channels (Nyström, 2006, p.523). Full details of said information flow are provided in Section 2.3.3.2.5. Such detailed analysis of relationships among components and the structure of a system, e.g. communication channels for information flow, is not present in any of the other systemic or traditional approaches (Preece, 2013).

Criterion 10: Being able to design/redesign in detail the joint task undertakings and structures for collaborations in the system: The purpose of SSM, SODA, and SCA is not in line with the system's structural design/redesign, nor do they offer the criteria for system design and tasks/roles set-up and development. SSM mainly focuses on arranging an environment where learning about the issues can take place. SODA's core objective is about the design of a particular strategy for implementation. SCA is rather an additive approach. The strategy development is incremental. SCA does not aim at a final product of a full strategy.

Hence, it is related to strategy development instead of technicalities of designing the joint tasks in detail. VSM is used as a blueprint to guide the design/redesign of the functions and tasks/roles and to establish why they relate to each other (Mingers and Rosenhead, 2001). It also models/designs the required joint tasks. This means that details of structures for collaborations are considered. Actherberg and Vriens (2002) use VSM and develop 31 domains of knowledge required for the system to be effective. These domains can be used for the research on knowledge sharing.

Criterion 11 – Providing a detailed analysis of the system's components: According to Flood and Zambuni (1990), VSM offers principles for the system's diagnosis. The result of such assessment is the provision of a detailed analysis of the system. According to Preece (2013), such detailed assessment of interactions among components and the structure of a system cannot be found in any of the other systemic/non-systemic models. This could justify why SSM, SODA and SCA do not deal with detailed evaluation of the system's components.

Criteria 12 – Analysing, measuring and managing performance: SSM, SODA and SCA are very generic when it comes to the measurement and management of performance. VSM does this with its three measures of productivity, latency and performance. These measures are devised based on the actuality, capability, and potentiality of the system (Beer, 1985). More details about VSM and information flow are provided in Section 2.3.3.2.6.

Having evaluated SSM, SODA, VSM and SCA based on the 12 criteria above, the situation is summarised in Table 6. The assessment based on these criteria leaves no doubt that using VSM is the most feasible approach to be used in this research.

Pillars	Required characteristics of the model for this research	SSM	SODA	VSM	SCA
Systems Characteristics	1) Being able to identify a system to model.	YES	YES	YES	YES
	2) Being able to establish a holistic comprehension of the system	YES	YES	YES	YES
	3) Being able to model participants' subjective interpretations and understanding.	YES	YES	YES	YES
	4) To build the model of the system based on facilitation of participants.	YES	YES	YES	YES
Engagement of stakeholders	5) Being able to build a qualitative model.	YES	YES	YES	YES
	6) Being able to advance participants' learning about the situation	YES	YES	YES	YES
	7) Being able to aim for politically viable outcomes.	YES	YES	YES	YES
Value of model building	8) Being a generic model to be used in multiple contexts.	YES	YES	YES	YES
	9) Being able to model information flow.	NO	NO	YES	NO
	10) Being able to design/redesign in details the joint task undertakings and structures for collaborations in the system.	NO	NO	YES	NO
Structured analysis	11) Providing a detailed analysis of the system's components.	NO	NO	YES	NO
	12) Analyzing, Measuring and Managing performance.	NO	NO	YES	NO

Table 6: Assessment of Modelling Approaches Based on Pillars and Characteristics Required for this Research

In order to get the best use of VSM for complexity management in the context of knowledge sharing and learning, the key features, mechanisms, and characteristics of the model are explored in the next section.

2.3.3.2. Viable System Model for Complexity Management

The viable system model (developed by Stafford Beer in 1972) is underpinned by systems thinking and cybernetics science, i.e. the science of effective organisations (Leonard, 2006), and is a generic model (Johnson and Liber, 2008). The viable system model is used as an organisational design instrument as well as a diagnostic tool to detect and reveal the weaknesses in the existing system. Providing such capabilities and applicability, this model has been highly appreciated among managers, system evaluators and consultants (Devine, 2005; Snowdon and Kawalek, 2003; Jackson, 1988). A viable system is defined as any system which is arranged and organised so as to meet and address the survival demands in the dynamically changing environment that surrounds the system. The viable system model features a specific organisational structure, making the system autonomous and capable of reproducing itself (Beer, 1984). The key to systems' survival is said systems' adaptability. This adaptability represents the capacity of the system, which allows it to exist and generate its identity as well as to survive the internal and environmental disturbances (Beer, 1984). Since the viable system model assists in understanding and handling such internal and external disturbances, it is regarded as a model of complexity management (Schwaninger, 2004). Within the scope of internal and external problems, complexity can refer to a system's capacity to maintain a large number of varied conditions, organisational states or behavioural modes that need to be managed (Schwaninger, 2009). According to Beer (1973), the viable system model is grounded in Ashby's law of requisite variety, variety engineering, and autonomy at local level, as well as recursion. It consists of five systems and ten channels and seeks to model an organisation in striving to survive the ever-increasing complexity of its environment.

2.3.3.2.1. Viable System Model: A Viable Organisational Structure

There are five systems, as well as six vertical and four horizontal channels, in the structure of the viable system model. According to Jackson (1988), the aim of the channels is to facilitate and maintain the communication and interactions among the five systems. The channels also support the coordination as well as the control. Beer (1985) emphasises that responsible for organisational cohesion is the equilibrium between operational components (as the sum of horizontal varieties) and vertical components (as the sum of vertical varieties) (p.84). Figure 4 illustrates the structure and interconnections in the viable system model and Table 7 presents its vertical and horizontal channels.

Channels	Descriptions
Vertical	**C1:** Channel that connects and absorbs and manage the variety between local environments i.e. the environment of each primary activity.
	C2: Channel that connects the various primary activities to each other.
	C3: Channel for corporate intervention (system 3 – system 1)
	C4: Channel for bargaining for the resources (system 3 – system 1)
	C5: Channel for conflict resolution and coordination (system 2)
	C6: Channel for monitoring and audit (system 3*)
Horizontal	Channel for interactions between the operational units and the environment
	Channel for interactions between the coordination and the environment
	Channel for interactions between the operational units and their direct management
	Channels for interactions between the operations and coordination

Table 7: VSM Vertical and Horizontal channels (adopted from Jose, 2012: p.61)

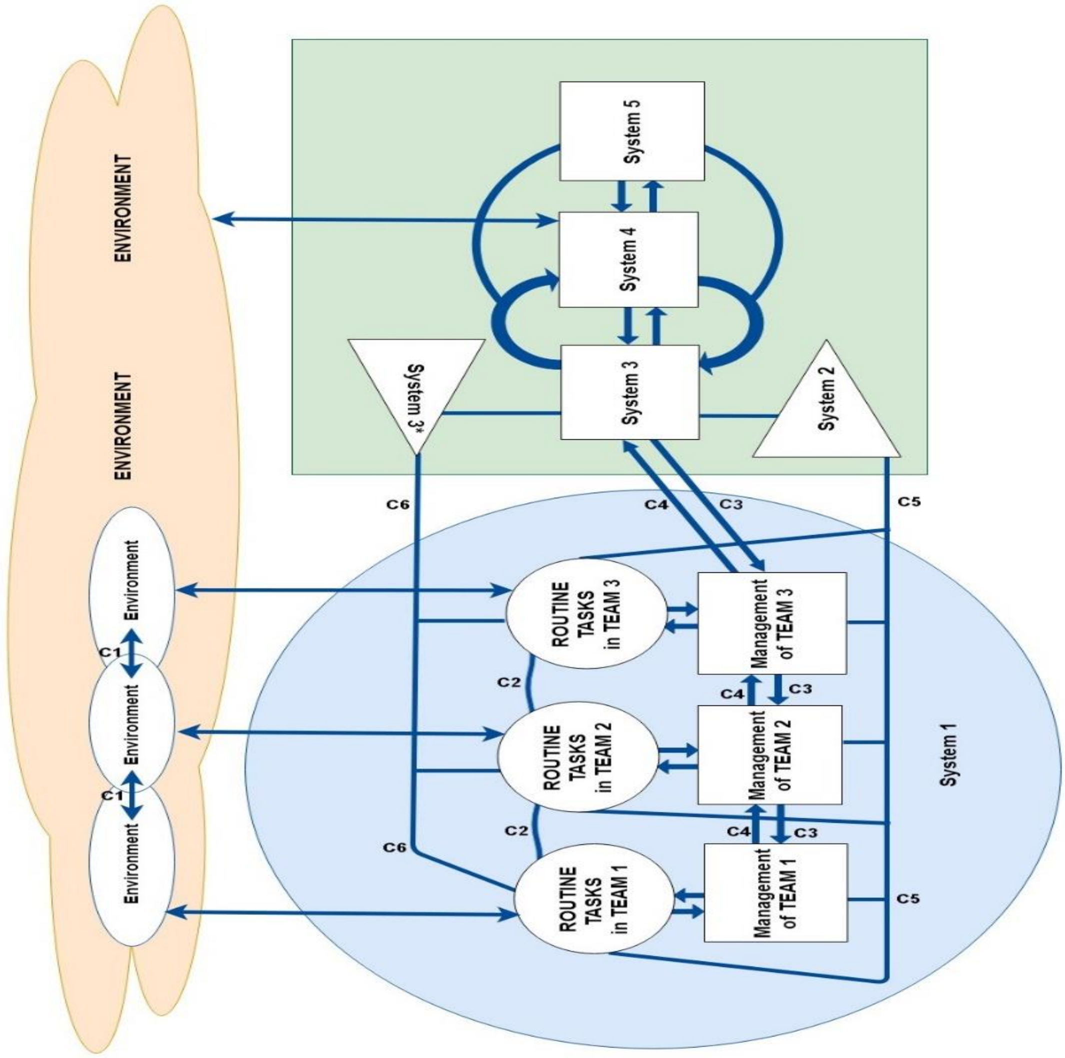


Figure 4: VSM Structure (adopted from Perez Jose, 2012, p.61)

System 1 (S1 – system for primary activities): This contains various primary activities which involve carrying out essential tasks of the organisation (Flood and Zambuni, 1990). The operations of these activities are autonomous, and conditional to maintaining the coherence of the whole system. System 1 interacts with the environment directly. Each primary activity in system 1 is a viable system on its own, due to the recursive property of the system.

System 2 (S2 – system of coordination): This relates to coordinative pathways of information and resources that allow the primary operational activities in system 1 to interrelate and communicate with each other. The coordination of these activities as well as scheduling the use of shared resources is also the job of system 2. All of these combine so that the system runs smoothly (Espinosa and Walker, 2011).

System 3 and 3* (S3 and S3* – system of management and control): This administers and manages system 1 in terms of representing and executing rules, instructions, rights and responsibilities. In a supportive manner, rather than being autocratic, it controls the primary activities (Leonard, 2007). It strives to synergise and optimise the system as a whole through linking systems 4 & 5 with system 1 to present the bigger picture of the primary activities. System 3* supports the other system 3 through audits. It cyclically checks issues that are not addressed by the normal system 3 and system 2 (Beer, 1981).

System 4 (S4 – system of intelligence): This looks outward and explores trends of the external environment as well as likely future opportunities/threats. It therefore enhances the adaptability of the system in order to stay viable. While strategising for the future, the demands of system 4 and system 3 must remain balanced in order to ensure that the system is able to carry on its current activities (Bustard et al., 2006).

System 5 (S5 – system of policy and norms): This defines and describes the system's mission, values, objectives and culture. It is therefore capable of official representation of the organisation to the outside (Jackson, 2000). It also monitors and manages the conflicts between system 3 and system 4 on resource allocation (Leonard, 2009). System 5 is generally carried out by top management. However, Beer stresses the significance of the contribution of all recursive levels to system 5, since VSM does not follow a hierarchical/top-down approach (Espejo and Gill, 1997).

Reflecting on the structure of VSM, a viable system does not have a hierarchy. This is because the communications and interrelations among parts of the system are never one-way, but instead act like an operationally-closed circular system. If an organisation follows these natural principles, it can more successfully adapt to its fast-paced changing environment (Beer, 1985). Based on the principle of viability, if a hierarchal organisation is effective in managing the complexities that are coming from the environment, then there is no need to apply VSM to it. However, VSM suggests that hierarchal organisations are less effective than non-hierarchal ones. VSM can help the hierarchal organisations to become more agile, more flexible and more effective. This means that when the hierarchal organisation becomes less effective or ineffective in responding to the changes in the environment, VSM can be applied to diagnose the issues and to redesign the defective parts of its structure. This is why the application of VSM as a non-hierarchal structure to any hierarchical organisation can be a good match.

2.3.3.2.2. Viable System Model: Variety Engineering and Homeostasis

In his first principle of management, Beer (1979) states that:

> *"Managerial, operational and environmental varieties, diffusing through an institutional system, tend to equate; they should be designed to do so with minimal damage to people and to costs" (p.97).*

In order to understand this principle, an organisation can be used as an example. In effect, an organisation may face problems coming from the environment. In response, the organisation possesses or develops solutions to deal with outside problems. The problems that come from the environment and the solutions that the organisation develop for the problems both create variety. The problems create environmental variety and the solutions create the organisation's variety. Variety is considered as the number of possible states that a system/organisation/entity can have (Beer, 1979). However, the method of dealing with these problems depends on requisite variety. The viable system model is underpinned by Ashby's (1956) law of requisite variety, which holds that "only variety can absorb variety" (Beer, 1973, p.11). The implication of this law in terms of complexity management lies in the way that variety should absorb variety in order for the system to remain viable. In other words, for an organisation to be effective, the variety of solutions must be equal to or larger than the variety of the problems. According to Leonard (2006), in order to match the variety of the system with the variety of its environment, the system should ensure that its internal variety is enhanced and the external variety that comes from the environment is decreased. Beer (1985) provides a basic picture of an organisation that works in its environment. The organisation itself consists of two elements, namely operations and management. Figure 5 illustrates this concept.

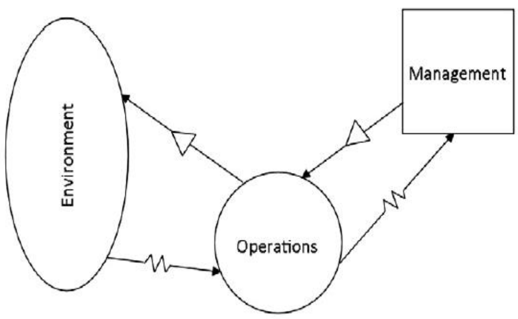


Figure 5: Variety in VSM (Beer, 1985, p.27)

Environmental variety significantly exceeds the variety in the organisation's operations (primary activity centres). Operations' variety also significantly exceeds the management that regulates or controls it. The point of Beer's first principle of organisation is to avoid the pointless discussions around the needs and wants of the organisation (and to consider needs and wants as purposes). Instead, the focus should be on addressing the higher order issues/problems of how to regulate the force of requisite variety.

According to Beer (1979), a manager does have many vehicles to increase his/her variety towards the operations, if the variety of the metasystem is low. Calling for a meeting, initiating/starting a newsletter in the organisation, and appointing staff to develop locational or functional policies are among many mechanisms which a manager can use to increase the variety. However, the amplifiers must be designed in such a way as to maintain the equation/balance of requisite variety (Beer, 1979, p.98).

In addition, it is vital to note that the style of management is also important and it is subjective, depending on the manager/change leader. One manager might establish a different state of polices/ethos than another manager. This difference relates to the management style, and both could generate the amount of variety required and deemed sufficient for the operation (Beer, 1979, p.98).

The process of balancing/regulating different varieties is called variety engineering. Variety engineering reduces or increases the variety through amplifiers and attenuators (Beer, 1984). A viable organisation is called a variety engineer and achieves homeostasis regulation through two mechanisms, namely verity amplification and variety attenuation. High variety thus must be attenuated to the number of possible states that the receiving entity can handle. Additionally, low variety must be amplified by the number of possible states that the receiving entity requires in order to remain self-regulated.

The process of generating balances facilitates the whole system's homeostasis. Homeostasis, according to Beer (1985), refers to the stability/balance of the internal environment in the system, despite the unpredictable pressures/forces from the external environment that the system has to cope with (p.17). Homeostasis can be the balance between system 3 (with its supportive monitoring and control) and system 4 (with its intelligent strategies around the system's future in the environment) – a balance that is monitored by system 5. There is also another homeostasis that aims to balance between system 1 and the environment. This can be through system 1's solutions for the current problems coming from environment. The next homeostasis is between system 3 and system 4. It preserves the right balance between the level of attention paid to the present and the level of attention paid to the future for each scenario that the organisation is dealing with (Beer, 1984; Hilder, 1995).

Beer (1984) states that "V.S.M. homeostats requisite variety is applied in three distinct ways: to the blocks of variety homeostatically related, to the channels carrying information between them, and to the transducers relaying information across boundaries" (p.12). The implications for how this transmission occurs are discussed in the next section.

2.3.3.2.3. Viable System Model: Information Flow and Communication Channels

Information is the lifeblood of the organisational system. VSM is able to model how information flows. It uses communication channels. The type of information that flows around the systems through communication channels is relative to tasks' distribution and specific to how various parts of the system as well as the system as a whole are performing relative to their particular purpose and goals. This is because the communication channels create connections between "actions" in system 1 and "decisions" in the metasystem (systems 2 to 5). System 1 and the metasystem can never be independent. These connections interlink the structural components of the system and they make sense only if associated with the system's purpose and identity (Golinelli and Gatti, 2001).

Beer (1979), in his second principle of organisation, states that:

> *"The four directional channels carrying information between the management units, the operation and the environment must each have a higher capacity to transmit a given amount of information relevant to variety selection in a given time than the originating sub-system has to generate it in that time" (p.99).*

While the communication channels take our attention to the contents that are being transmitted, according to Beer (1979), variety generation, as a capacity of the channels for transmission of information, is more important. He explains the information flow using the concept of variety, since variety is the number of possible states; he then asserts that "in a dynamic system there is a minimal time in which all possible states can be exhibited". Therefore, there is a "rate of variety generation possible per unit of time" (p.99). For example, a channel that carries a Morse code message must recognise a variety of states. These sates are: (1) the dot, (2) the dash, (3) the pause that separates the dot and dash within a letter, (4) the pause between letters, and (5) the pause between words (p.99). The message (information contents) can be anything. It can be a pizza order or a declaration of war. The point of the principle above is to examine whether sufficient variety exists in the structure of the channel itself, enabling it to register/record the number of states, which are assumed to be transmitted at a given rate.

In addition, Beer's (1979) third principle of organisation is concerned about information that crosses a boundary. He states that:

> *"Wherever the information carried on a channel capable of distinguishing a given variety crosses a boundary, it undergoes transduction; and the variety of the transducer must be at least equivalent to the variety of the channel" (p.101).*

Crossing the boundaries occurs through communication of information between the environment, and the operation (system 1) and metasystem (management in systems 2 to 5). The message that this information is assumed to convey must become comprehensible for the receiver. Hence, it should be translated to the language that the receiver is capable of recognising when crossing the boundaries. The transducer does act as a conversion mechanism. The transducer must be able to cope with and handle the variety that is provided by the sender, otherwise the channel would not be able to act as a conveyor of the requisite variety. This means that the transducer must distinguish/recognise at least as many states as the channels can communicate. In the Morse code example, this would mean that a receiver that is capable of receiving information at the rate of 40 words per minute would have enough capacity to accept a message conveyed at the rate of 25 words per minute. The assumption, however, is that the receiver is able to distinguish the pause between the letters from the pause between the dots and the dashes; otherwise, the receiver would lack the requisite variety to carry out this task (Beer, 1979, p.101) and the transducer would have to act as a variety attenuator. Therefore, in this case, the transducer would be failing in its purpose and any message would be distorted/denatured. Beer (1979) states that:

> *"I have often been amazed to hear senior managers reporting on different situations to the board in terms which attenuate the variety of that situation by an order of magnitude. Now it is true that the senior manager has a duty to condense the information he is transducing, although he often fails to discharge this duty by talking interminably. But he has a contrary duty to preserve transduction variety: that is he should not be portraying the complicated situation in a black-and-white fashion when it is capable of accommodating many shades of grey" (p.102).*

Since systems of the real world have too much variety (Hilder, 1995), the observer of the system copes with the reality in two ways. First, the observer can only "see" what he/she looks for, and filters out the "irrelevant" things. By doing this, the observer attenuates the variety of his/her environment. According to Hilder (1995), the human's variety attenuator originates from human physiology (e.g. observer cannot see ultra violet lights), individual endowment (e.g. some humans are tone deaf), and social conditions (e.g. family, or wider social environment). Second, the observer uses his/her logic/intelligence in order to increase the impact of his/her actions. By doing this the observer increases his/her own variety and amplifies his/her power over the environment.

It is evident that VSM deals with communication of information as well as structures that carry and transmit the information. Effective communication of information through channels and then processes of social interactions provide a facilitative internal learning atmosphere where knowledge can be generated. Such generated knowledge would also be shared, updated, and shared again. This is through circularity of social interactions and task involvements. In this arena, variety, as a key concept of VSM, can be used to deal with the complexities involved in the processes of knowledge sharing that the management has to deal with. Since the organisational resources are limited, the attenuation of varieties in the knowledge sharing process can be through facilitation of goal-orientations and giving directions towards the purpose of the system. It can also focus on variety amplifications through an effective mechanism of facilitation for internal social interactions and engagement throughout the social agents' knowledge network. This, in turn, increases individuals and collectives' knowledge capabilities in the system.

Having discussed the above, it is important to note that the information which flows through communication channels and the knowledge that is shared, are subjective and observer-relative. Whatever the observer interprets, his/her observation is always subjective and depends on his/her understanding and interpretations. The information he/she collects and the knowledge that he/she develops and shares through different communication channels are also relative to his/her understanding or the understanding of other people with whom he/she shares information and knowledge. In addition, the flow of information in a hierarchal organisation is different from that in a non-hierarchal organisation. In a hierarchal structure, information flows from the top down. In contrast, in a VSM structure, information flows bottom-up first and then top-down. This mobilisation or flow of information/knowledge from the operations to the meta-system and vice versa permits and promotes the learning to happen. Further, in hierarchal organisations, as the number of hierarchal levels increases, the chances of distortion of information also increase. This is because the process of information flow among layers is subjective to different interpretations of different observers. This would mean that the information intended to be shared from the top might reach the bottom of the organisation and be mistranslated and misunderstood (whilst going through different transductions). This results in less clarity and more distortion and confusion. In contrast, in heterarchical structures such as VSM there are not many layers, and hence there are not many levels of information transduction, which in turn means fewer mistranslations and observer-subjective distortions. This is because people in each layer receive the information based on the transductions. Such information is then shared in the same layer; hence, confusions are corrected and a shared understanding of the information is reached. This resembles self-regulation of communication in each layer and contributes to the quality of communication from one layer to the next in the heterarchical structure of the organisation.

2.3.3.2.4. Viable System Model: Performance and Outcome Management

The viable system model has the capabilities to facilitate the performance measurements. In Brain of the Firm, Beer (1972, p.163) describes three factors to characterise activities in an operation system. These components are actuality, capability and potentiality. Performance is the ratio of actuality to potentiality.

Actuality is defined as the present achievement of the system with its current resources and limiting constraints. Capability is explained as the best historical performance that the system has achieved in a time period based on current resources and existing constraints. Potentiality is described as what could be achieved through development of the resources, resolving the constraints, or both. The three measures of performance achievement are:

Productivity = Actuality/Capability

Latency = Capability/Potentiality

Performance = Latency * Productivity

For example, let us assume that in a production plant for iPad, the actual production of iPads is 4,000 iPads per year (based on existing conditions, resources and constraints). The capability of the production plant, based on its historical data under the same existing conditions of resources and constraints, is 5000 iPads per year. The potentiality of this production plant is 6,000 iPads per year, if another assembly line could be added and workers could be working full time rather than part time. In this scenario:

Productivity = Actuality/Capability = 4,000/5,000 = 0.80 i.e. 80%

Latency = Capability/Potentiality = 5,000/6,000 = 0.833 i.e. 83.3%

Performance = Latency * Productivity = 0.833 * 0.80 = 0.66 i.e. 66%

When actuality diverges from capability, because someone performed something well or something worse, then the control system receives an algedonic alert. If remedial action, implementation of a good method/technique or correction of a mistake, is not carried out in the required time, there will be an escalation of alerts. Best practice heuristics emerge from orderly routine responses and feedback in system 3*. Such heuristics are continuously observed for improvement via system 4.

2.3.3.2.5. Viable System Model: Recursion and Local Autonomy

The concept of recursion in the viable system model refers to a structure that contains autonomous components within autonomous components in a nested way. In the same way, a viable organisation is comprised of viable entities and is itself embedded in more inclusive viable entities (Schwaninger, 2006). Each entity, in structural terms, replicates the whole of what it is embedded in, from beginning (producing the primary tasks) to end (supporting and managing the primary activities), i.e. all processes relevant for maintaining its identity and the purpose that it exists for. According to Beer (1985), when the system in focus is a viable organisation then "it may have more than one next higher and next lower recursion" (p.6). It is prevalent therefore that recursive entities are multidimensional or perhaps circular (cf. Schwaninger, 1994). As a result, the complexity that comes from the environment to challenge the system can be managed through distribution in these many layers of recursion (Schwaninger, 2006).

Recursion in the viable system model also relates to the concept of autonomy at local level. This autonomy represents the freedom as well as the responsibility that the local system endures to regulate itself. This means that lower recursive layers have power to make decisions for their own operations, as long as they do not conflict with the coherence of the whole system (Schwaninger, 2006). The recursion and the autonomy at local level facilitate direct and instantaneous management of problems locally (Lewis, 1997). For example, the operations of primary activities in system 1 are autonomous, and conditional to maintaining the coherence of the whole system. This releases upper level management from a pointless involvement in the problem handing (Espinosa and Walker, 2006).

2.3.3.2.6. Viable System Model: Self-Organisation vs. Guided Self-organisation

Self-organisation basically relates to a re-organisation of structures, processes and/or functionalities, being formed/produced organically in a dynamic way in the system. Haken (1977) illustrates the concept of self-organisation with an example from human actions:

> *"Consider, for example, a group of workers. We then speak of organization or, more exactly, of organized behaviour if each worker acts in a well-defined way on given external orders, i.e., by the boss. We would call the same process as being self-organized if there are no external orders given but the workers work together by some kind of mutual understanding" (p.191).*

Notably, the "boss" is considered external to the team of workers. Considering the team of workers as a system that actually re-organises its structure, there is no direct involvement of the boss in the re-formation of the teamwork structure or the team's functionality.

Self-organisation, according to Bonabeau et al. (1999), is characterised by (1) the various interactions among the system's components/agents without any centralised regulation/control, (2) the reflective positive and negative feedback, and (3) the increase in modification of the system's behaviour in order to adjust to the changes and to adapt to the environment. Fuchs (2002) argues that, in social systems, the various interaction/social relations among agents are facilitative of social cooperation. Social agents benefit from the common frames of references that exist among them. Through cooperation, they can accomplish objectives which they cannot reach individually. Social cooperation supports the emergence of new qualities in the system such as collective capabilities and social knowledge. This is because social cooperation underpins the process of fair and equal information flow/knowledge sharing which supports the process of learning and development. On the other hand, social competition is a form of social interaction based on which power and domination help some agents to take advantage of the others. Here, new qualities of the system also emerge from social competition. These qualities are power-orientated and of advantage-taking nature. Information, in this case, does not flow equally among all social agents. Hence, the knowledge which emerges based on social interactions of a small group turns into a source of power for them, which fuels the social competition with the other agents in the system. The information that is being shared in processes of social cooperation and social competition is of a cooperative and competitive nature, respectively. Social cooperation produces inclusive information/knowledge and social competition establishes exclusive information/knowledge. According to Fuchs (2002), the exclusive social information cannot be considered as an outcome/quality of the self-organisation process. This is because not all of the concerned social agents are involved in the process, and they are not equally using shared resources and tools in the system.

Fuchs (2002) refers to self-organisation as a mechanism for the system's effectiveness and continuity over time and continuous information/knowledge creation:

> *"A social system organises itself permanently in order to maintain itself and it permanently produces and changes social information" (p.229).*

And:

> *"Each time a system organises itself, information is produced; hence all self-organising systems are information-generating systems" (p.225).*

The process of self-organisation can also be studied from the entropy/negentropy perspective. A self-organising system moves away from entropy. Demetis and Lee (2019) define a self-organising system as "a system that eats energy and order from its environment" (p.5). This shows there is a high possibility that the system will become negentropic, at least in the short term. Negentropic systems, as discussed in Section 2.3.2.1.2, are charged/loaded with energy and information from the environment. The loaded energy and information need to be transduced/translated within the system in order to become relevant and applicable. The translated version of such information generates new knowledge when people understand it in relation to the system. This is because it facilitates the internalisation/absorption of the incoming energy and information more effectively in the internal processes of the system. Said system, according to von Foerster (2003), is able to enhance its own order internally. Self-organisation is recognised as a process based on which the system's internal varieties are enhanced/increased. In turn, such increase in internal varieties creates the dynamics of the system (Prokopenko and Gershenson, 2014; Prokopenko, 2014, 2009; Polani et al., 2013; Ay et al., 2012). This is part of the system's self-organising behaviour. Based on Demetis and Lee (2019), the self-organisation process (including the transduction/translation) is, however, observer-relative. This is because in producing information/knowledge, the observer uses his/her own frame of reference.

In this vein, guided self-organisation can be considered as leading the process of steering the dynamic of the system towards a desired outcome or the system's configuration. According to Polani et al. (2013), guided self-organisation has three characteristics. First, there is an increase in the re-organisation of structures, forms and/or functionalities. Second, there is no explicit guidance from any external agent for the local interactions/collaborations. Third, task-dependent goals are considered in line with task-dependent limitations/constraints.

Guided self-organisation aims to lead/guide the outcomes of the process of self-organisation through leveraging its strengths (Polani et al., 2013). This may seem paradoxical. Guided self-organisation strives to lead/guide the system into a more suitable structure/form or functioning state, and at the same time it attempts to increase the range of options through an examination/exploration within the existing search arena. In the other words, the guidance suggests 'control' and self-organisation suggests 'autonomy'. Although looking contradictory at first sight, nonetheless the distinction between the notions of control and constraint can resolve this paradox. This is achieved through placing some constraints within the dynamics of the system in order to facilitate the interactions rather than precisely controlling the transition of the system, towards a better system state (Prokopenko and Gershenson, 2014).

In social systems, self-organisation can be implemented through two mechanisms, namely reducing the conflicts/frictions (e.g. scaling down the social competition) and increasing synergy by employing mediators/facilitators. Since complexity depends on the level and scale of varieties (Bar-Yam, 2004), these mediators/facilitators have to match the variety of the environment with the internal variety on multiple scales through self-organisation mechanisms (Gershenson, 2011) such as social cooperation, as discussed earlier. According to Gershenson and Rosenblueth (2012), implementing these mechanisms leads to systemic outcomes that are closer to optimal performance.

In the example mentioned above for the concept of self-organisation, an example of guided self-organisation would be the boss reminding different working teams of the deadline for the company to deliver a project with several deliverables. In this case the boss is not actually involved in completing the pieces of the jobs or controlling the functionalities, and instead motivates/alerts the teams regarding managing the time. Another example of guided self-organisation would be investing in a new technology to speed up the work of the teams in accomplishing their tasks and deliverables. An example in this regard could be the boss cancelling all workers' holidays in order to increase the organisation's internal varieties in terms of the number of experts who are required to work in different teams in order to meet the expectations of the customers (i.e. external varieties). From the entropic perspective, this example reminds us of the benefits that variation (knowledge varieties of the experts) can have in terms of guiding the process of self-organisation by restricting the entropy. After delivering the project, however, it would be necessary for the boss to prompt and motivate the experts to take a holiday in order to maintain the regulations as well as work-life balance. This is understood as increasing the entropy in the system when necessary.

With the examples above, it is pertinent to mention that teams are considered focal units of self-organisation in the social systems. Hence, it is vital to investigate the impact of self-organisation in socio-technical teams. The next section sheds some light on this area.

2.3.3.2.6.1. Self-Organisation in Socio-Technical Teams

According to Karhatsu et al. (2010), the main mechanisms that facilitate building a self-organising team are autonomy along with communications and collaborations. Organisations build self-organising teams in order to improve productivity and enhance the quality of their products or services (Moe et al., 2009).

Compared with excessively plan-driven teams, self-organised teams bring decision making to the team level; hence, the team is able to quickly and appropriately respond to the environment and its changes. Being multitasked, they achieve this through re-organisation of the duties and tasks in the team based on the situation which arises (Fenton-O'Creevy, 1998; Tata and Prasad, 2004; Nerur et al., 2005). They set and achieve their own goals via participation and engagement among team members (Nerur et al., 2005). For example, in socio-technical systems the self-organising teams are allowed to organise themselves in performing their tasks (Herbst, 1962) using their autonomy in terms of method of working as well as the pace of the work (Hackman and Oldham, 1976).

Limiting the autonomy has a harmful effect on people's performance. This is because controlling people indicates that the management have no trust in them (Kramer, 1999). Instead, autonomy in the self-organising teams averts stress and anxiety about the tasks (Frese, 2008).

The autonomy that is observed in self-organising teams also positively impacts the competence of team members (Burr and Cordery, 2001). In addition, it encourages the team to take the responsibility of coordinating with other teams (Batt, 1999), and to develop more proactive task orientations (Parker et al., 1997) as well as to engage in achieving the tasks through using their personal initiatives (Moe et al., 2008).

With the autonomy increased, the confidence and capabilities of team members for undertaking a wide range of tasks develop further (Parker and Wall, 1998). Hence, they master new duties and gain new skills (Gist and Mitchell, 1992). When people are armed with this higher role-extent competence, they proactively set, pursue and endeavour to achieve goals that are more challenging (Parker et al., 1997).

Cherns (1976) provides nine principles of socio-technically designed systems. These principles are: (1) Minimal Critical Specification, (2) Boundaries, (3) Multi-functionalities, (4) Support Congruence, (5) Information Flow and Feedback, (6) Incompletion, (7) Compatibility, (8) Human Values, (9) Socio-technical Criterion. Table 8. provides these principles as well as their explanations and implications.

Principle	Description	Implication
Minimal Critical Specification	• The emphasis is on only minimum provision of instructions on how the roles should be carried out.	• Reliance on teamwork (Nerur et al., 2005), • Common ownership of the results (Dyba and Dinsoyr, 2008)
Boundaries	• Small collocated teams	• Less attention about outside issues (Kakar, 2017) • Flexibility and overall efficiency (Turk et al., 2005)
Multi-functionalities	• undertaking multiple tasks, redundancy in functions	• Flexibility (Moe, et al., 2008), • Greater degree of skills variety (Kakar, 2017)
Support Congruence	• A broad range of training that are relevant to or facilitate performance of the tasks as well as meeting organisational needs should support team members' activities.	• Team member undergo a broad range of training, facilitative supervision, coaching, etc. (Kakar, 2017)
Information Flow and Feedback	• Feedback refers to information provided via communication about the effectiveness of the team. This is a double-loop learning and is aimed at increasing the autonomy.	• Project retrospective feedback (Hackman and Oldham, 1976), • Greater feedback on performance (Kakar, 2017) • Face-to-face interactions, engagement and communications facilitate tacit knowledge sharing (Beck, 1999)
Incompletion	• Design is an ongoing process and result of continuous iterations of learning as well as experimenting.	• Work plan/design is not fully indicated upfront (Hislop et al., 2002), • Team members develop significantly more reflective cycles or iterations in order to find solutions (Kakar, 2017)
Compatibility	• The focus is on fit/match between the method or approach and the sought-after solution/outcome with attention paid to people's interactions.	• The most effective strategy is most likely to put forward by those who operationalise the plan (Emery, 1993), • Greater participation in the planning process (Kakar, 2017)
Human Values	• This refers to sincere attention to needs of people as well as improvement in the quality of working-life through the role/task's enrichment. People have the ability to engage in the management decision making and they can be empowered to make their own decision.	• Maximising individual and team's autonomy in order to humanizing the work environment (Klein, 1989), • Higher understanding of personal and professional desires / requirements (Kakar, 2017)
Socio-Technical Criterion	• Mistakes should be detected at its source and be resolved there.	• Team members retrospect and review (Scrum Alliance, 2008) and even can change the norms (Beck, 1999)

Table 8: Cherns' (1976) principles of socio-technically designed systems and their implications

Kakar (2017) tests these nine principles of socio-technically designed systems to compare agile teams (which are self-organised) with extensively plan-driven teams. He finds that in all of the nine principles the level and extent of self-organisation in agile teams are significantly higher than those of plan-driven teams. He also finds that self-organisation positively influences the motivation as well as the innovation of socio-technical teams. Practising self-organisation, however, faces some barriers. People are more familiar when it comes to commanding and controlling culture. Adapting to norms of self-organising culture is therefore not easy. In addition, whilst multitasking is beneficial for the system, recruiting or training multitasking people is difficult, time consuming and expensive. Further, self-organised teams might not have complete control over their human assets, since team members might be shifted to other projects based on priorities in the organisation (Moe et al., 2008). Moreover, although organic (flat and flexible) structures of the organisation assist in self-organisation, adaptability and learning in the teams, nonetheless, according to Cockburn and Highsmith (2001), misalignment between team structure and organisational structure should be avoided because it can be counterproductive to both of them. Finally, managers might not be willing to give up control.

It is important to note that the mechanisms of self-organisation can lead to autopoiesis (Gershenson, 2015). The next section sheds some light on the concept of autopoiesis and its role in the operation of small teams. The discussion will be in the scope of complexity management in organisations.

2.3.3.2.7. Viable System Model: Autopoiesis and its Role in the Operation of Small Teams

Autopoiesis is defined as producing self. The word autopoiesis originates from the Greek words auto (self) and poiesis (creation or production). Rooted in biology, the original meaning of autopoiesis refers to the material self-production of cells through organisations of its own molecules. This theory was developed by Maturana and Varela (1980). They state that:

> *"An autopoietic machine [system] is a machine [system] organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network" (Maturana and Varela, 1980, pp.78-79).*

This means that an autopoietic system reproduces itself because of its structure and organisation. According to Maturana and Varela (1987):

> *Organisation is "[the] relations that must exist among the components of a system for it to be a member of a specific class" (p.47).*
>
> *Structure is "the components and relations that actually constitute a particular unity and make its organisation real" (p.47).*

Autopoietic systems have four features, the first of which is autonomy. Autonomy revolves around the idea of a system being able to stipulate and lay down its own rules, procedures and its exhibiting behaviour. The second feature is individuality. Individuality suggests that whilst autopoietic systems are keeping up with their organisations, they also maintain their identities in an active way. The third feature is organisational closure. In order to remain alive and effective, a system needs to be organisationally closed. However, organisational closure does not reject the input from outside the system (e.g. environment). The fourth feature is self-defining boundaries. The internal relations and dynamics generate the elements/components of the boundaries. The process of autopoiesis is contained within the system's boundaries (Maturana and Varela, 1980, p.80).

Autopoiesis has also been used in domains other than biology. This generalisation can be viewed as an adaption rather than an adoption of the concept, since the notion of living cannot be easily translated/defined in non-living systems in precise terms. The use of this concept in, for instance, sociology, is what Luhmann (1986) has developed as social autopoiesis for which the original meaning of autopoiesis is changed to explain a wider array of phenomena. Hence, a broader meaning of autopoiesis is the self-production of a system using its underlying substances and mechanisms in an independent way. Therefore, it becomes possible to talk about a society's self-production of its own norms (i.e. a non-material thing). Social autopoiesis has been studied by Luhmann (1986, 2009), Gidens (1979, 1984) and Fuchs (2003, 2007).

The application of autopoiesis in organisations has been studied by Beer (1984, 1985), Bakken and Hernes (2003), Maula (2006) and Magalhaes and Sanchez (2009). Beer (1980) states that, according to Maturana and Varela (1980), the meaning and purpose of autopoiesis is:

> *"to understand the organization of living systems in relation to their unitary character. This formulation of the problem begs the question as to what is allowed to be called a living system, as they themselves admit" (p.68).*

According to Beer (1980), for a social system to be autopoietic, it is not required to be living:

> *"The fact is that if a social institution is autopoietic (and many seem to answer to the proper criteria) then, on the authors' own showing, it is necessarily alive. That certainly sounds odd, but it cannot be helped. It seems to me that the authors are holding at arm's length their own tremendously important discovery. It does not matter about this mere word "alive", what does matter is that the social institution has identity in the biological sense; it is not just the random assemblage of interested parties that it is thought to be. When it comes to social evolution then, when it comes to political change: we are not dealing with institutions and societies that will be different tomorrow because of the legislation we passed today. The legislation – even the revolution – with which we confront them does not alter them at all; it proposes a new challenge to their autopoietic adaptation. The behaviour they exhibit may have to be very different if they are to survive: the point is that they have not lost their identities" (p.68).*

Beer (1980) further mentions that:

> *" ... any cohesive social institution is an autopoietic system because it survives, because its method of survival answers the autopoietic criteria; and because it may well change its entire appearance and its apparent purpose in the process. As examples I list: firms and industries, schools and universities, clinics and hospitals, professional bodies, departments of state, and whole countries"* (*p.71).*

Having discussed the concept of autopoiesis as well as the features of autopoietic systems, it is important to know how autopoiesis operates in teams. As discussed in Section 2.3.3.2.6, teams are considered as focal units of organisational and social systems where self-organisation takes place. In turn, the mechanisms of self-organisation can lead to autopoiesis (Gershenson, 2015). In this arena, according to Karhatsu et al. (2010), the main mechanism that facilitates building self-organising teams is autonomy along with communications and collaborations. While autonomy is a feature of autopoietic systems, communications and collaborations in the social systems in general and within the teams in particular can be explained through the origin of humanness in the biology of love (Romesin, and Verden-Zoller, 2008). The central realm of cooperation emerges through basic feelings/moods of reciprocal respect, fairness, support, care, trust and acceptance (as features of love) as opposed to competition, rivalry, violence or arrogance. As discussed in Section 2.3.3.2.6, competitions and competitive interactions cannot be considered as a mechanism of self-organisation in teams. The cooperation, collaboration as well as communications (by which one is structurally coupled with others in language) facilitate the human species' attempts to conserve through features of love and to evolve. This is not to relate the responsibility of one towards the others to the ethical imperative, but rather to what naturally emerges and develops from a way of living (i.e. human experiential existence) in the biology of love, which is also called social consciousness (Romesin, and Verden-Zoller, 2008). The argument here is that the biology of love motivates people to communicate, cooperate and collaborate with each other. From the organisational perspective, therefore, the aforementioned biology supports self-organisation in the teams as well as at organisational levels, which in turn leads to autopoiesis. This is because the dynamic actions/interactions of people in an organisation create/recreate spontaneous structures of a singular dynamic by keeping up the processes of dynamic relations. As long as these structures and processes are (re)generated, autopoiesis, i.e. self-production of the system, continues.

2.3.3.2.8. Viable System Model: Pathological Symptoms in Autopoiesis

According to Beer (1979), when an organisation produces itself, it reveals to the outside that it has an identity and it retains said identity. In addition, Hilder (1995) states that self-organising systems are perceived to embrace many purposes. Some purposes are out of sight. Common in all, however, is the need to stay viable. This means that they all aim to maintain their existence, until the time when their purposes are accomplished at least. The ultimate testimony of viability is autopoiesis, which means that the viable system is guided towards the course of its own production (Beer, 1979, p.405). Beer (1984) further explains that, in any viable system, it is system 1 (S1) that contains the components capable of producing self (p.14) and as Maturana (1987, 1992) specifies, they are autopoietic generators. Beer (1979) also states that:

> *“Systems Two, Three, Four, Five are not in themselves viable at any level of recursion: therefore they should exhibit no internal autopoietic behaviour whatever. They often do and that is the source of the pathological time-usage. […] Hence, instead of seeking a chimerical numerical constant as an invariant in the pathological autopoiesis, it is necessary only to study the actual behaviour of Systems Two to Five, conceived of as services to the autopoiesis of system One” (p.412).*

Therefore, in some organisations, systems 2, 3, 4 and 5 of an organisation might exhibit a tendency to become autopoietic. However, viability is a feature that can only be embodied in system’s totality and in the elements of system 1. If any of sub-systems 2, 3, 4 or 5 of a system turn autopoietic, they will be pathologically autopoietic and will threaten the viability of the whole system. The responsibility of system 2, 3, 4 and 5 is to work for the whole system by sponsoring/promoting the primary activities of system 1. They should not turn into viable systems in their own right at any given recursion level. They will cost the whole system if they become autopoietic. An example of this situation is the typical mistake of bureaucracies, where any of their systems (2, 3, 4 or 5) become pathologically autopoietic. According to Beer (1979), within the bureaucracies, like in any social system, an “Establishment” can emerge (p.412). He clarifies that “The Establishment includes everyone who plays a role in the rituals of pathological autopoiesis” (p.13). Further, he states that:

> *“'The Establishment' in any social system comes into being at the point when the vital principal of autopoiesis consumes energy greater than that needed to maintain cohesiveness through the appropriate number of viable recursions that marks its claim to organisational identity as a set of embedments of System One. 'The Establishment' presents autopoietic activity on the part of systems Two, Three, Four or Five; and this constitutes a pathological symptom of the viable system" (Beer, 1979, p.412).*

Referring to “when the vital principal of autopoiesis consumes energy greater than that needed to maintain cohesiveness”, another example can be a hospital. A simple test which can be used to uncover whether the autopoietic activities of a hospital are pathological or healthy is to ask what proportion of everybody's time is spent on healing and what proportion is spent on the autopoiesis of the medical professionals. The activities of systems 2 to 5 in a hospital are supposed to be there to serve the activities and processes of healing (i.e. system 1's tasks). If the amount of time spent on self-production in systems 2 to 5 (e.g. autopoiesis of the medical professionals) goes beyond the minimum required for maintaining the system as a united and interconnected whole (cohesiveness), then systems 2 to 5 are in an unhealthy state, and hence pathologically autopoietic (Beer, 1979, pp.408-412).

Reflecting on what has been discussed so far with reference to the viable system model and its characteristics, the question is how this model has been used in knowledge sharing processes and what the literature has on offer in this regard. The following section sheds some light on these notions.

2.3.3.3. Viable System Model for Knowledge Sharing Processes

The literature review of this thesis shows that there is no documented study which focuses on the process of knowledge sharing from the perspective of the viable system model. Widening the scope of review to include studies on knowledge management using the viable system model, it is found that there exists only a few. Reviewing these very few, however, brings to light some common features which can inspire ideas for developing studies around the process of knowledge sharing from the viable system perspective. So, let us see what is on offer.

Leonard (2000) looks at an organisation as a whole system and provides the structure of knowledge management processes. She argues that the concept of variety can describe many concepts of knowledge management. Accordingly, in an organisation, the variety of any circumstance is absorbed and balanced close to its source through built-in supportive controls or casual give and take. Considering organisational limitations, management may amplify as well as attenuate the variety of the operations it manages. Examples of variety amplification can be publishing limits and opportunities, as well as decisions in the organisation, whilst examples of variety attenuation can be standard setting and providing direction for the operation. Best practice, in this regard, is to provide the operation with sufficient autonomy and resources in order for people to observe and learn from their growing experience.

Relating to the concept of recursion, Leonard (2000) reveals that recursive relations, however, are not necessarily to be based on hierarchy of orders. In fact, they are bound by little or no formal power. This facilitates local autonomy in each system as long as it is consistent and fit with the main goal of the organisation.

Further, Leonard (2000) refers to the notion of homeostasis as a state of the system's regulations so that internal conditions remain stable and relatively constant. She states that homeostats are present in all connections and links in viable systems. However, special attention must be paid to the homeostats between the control system and the intelligent system. This is because such homeostats play a critical role in keeping the organisation, as a whole, in a condition of dynamic stability. This direct connection facilitates far more knowledge sharing between the control system and the intelligent system, whilst also regulating their actions based on continuous learning. Such homeostats may also be involved in the team's knowledge sharing processes to expand their knowledge of one another as well as their future environments.

Leonard (2002) reminds that self-reflection and self-knowledge are needed in each system in order for the organisational capabilities to be fully realised. In terms of expanding knowledge of future environment, the intelligent system scans the environment in order to devise new strategies to make the system capable of adapting to the environment. The new strategies have to rely on assimilation of previous experiences, making use of them, learning from them and developing capabilities continuously in line with preserving the system's identity.

Based on the same rationale for variety engineering (amplification, attenuation) and homeostasis, Yang and Yen (2007) use the viable system model and Nonaka and Takeuchi's (1995) four conversion strategies of internalisation, combination, socialisation and externalisation for the processes of knowledge management. They develop a viable system framework for organisational knowledge which integrates knowledge into organisational goals, classifying organisational knowledge into four categories of transactive, bureaucratic, entrepreneurial and constructive.

This framework differs from that of Leonard (2000), with its specific focus on the social character of organisational knowledge built upon Chinying Lang (2001). From the organisation perspective, organisational context is a main source for the emergence of valuable knowledge. Central to effective work on knowledge are the human aspects of the organisation. In other words, it is vital for knowledge management functions to connect people and help them to brainstorm together and share what they think is beneficial for their community in terms of knowledge.

It is, however, important to note that there exists a limitation for knowledge representations. For example, knowledge management programmes that are solely dependent on IT cannot effectively share and deliver knowledge. Overall, these considerations reveal that Yang and Yen (2007) adopt a socio-functionalist perspective on the viable model of knowledge management. It appears that further development of their arguments can potentially proceed with a viable system perspective for the knowledge sharing process whilst considering knowledge networks as well as communities of practice.

From the knowledge management perspective, Barragan-Ocana et al. (2012) attempt to explore and compare communities of practice with complex systems. They refer to communities of practice as a learning system which is generated and developed from the common interest of individuals experienced in a knowledge area. They state that the stability and viability of knowledge management in communities of practice are ensured if they are managed through a viable system model, so that their environments, operational components and the meta-systems are understood.

Achterbergh and Vriens (2002) also relate to the viable system model and consider a cybernetic view (functional perspective) for knowledge in the organisation. They apply underlying principles of the viable system related to the processes of knowledge management and provide a list containing domains of viable knowledge to be managed. Table 9 illustrates how these domains are connected to two of the core processes of knowledge management (i.e. generating and applying). Although Achterbergh and Vriens (2002) do not explicitly specify what is to be shared, this table clearly hints at which knowledge should be shared with which system so that the whole system of organisation remains viable. In this Table, F1, F2, F3, F4 and F5 represent primary activities, coordination, control, intelligence, and policy/governance, respectively.

Preece et al. (2013) use these domains of viable knowledge to structure information processing complexity, through which they identify issues responsible for reducing the viability of systems of operation and control. However, their case studies are related to natural disaster management. Further, there is no evidence in the literature on how these domains of viable knowledge can identify issues in knowledge management or specifically in knowledge sharing where social networks or communities of practice also come into effect.

Yang and Yen (2007) refer to socialisation as a strategy for the conversion of knowledge drawn from Nonaka and Takeuchi (1995). While this is theoretically, empirically, and heuristically the most useful approach to knowledge sharing, they do not provide further implications on how to link socialisation with the concepts of the viable system.

Knowledge Domain	F1	F2	F3	F4	F5
Goals set by, Performance and Modus Operandi of the Primary Activity in F1	G, A	A	A	A	
Organisational Goal	A		A	A	G, A
Expected performance of the primary activity (Goals for F1 activities)	A		G, A		
Monitoring and control practices by F3	A		G, A		
Goal and Performance misalignment	A		G, A		
Causes and Consequences of goal and performance misalignment	G, A		G, A		
Actions to counter goal and performance misalignment by F1	G, A				
Heuristics to implement counteractions	G, A				
Anti-Oscillatory Measures	A	G, A			
Interdependencies between F1 Activities		G, A			
Actual Oscillations		G, A			
Actual Performance Loss due to Oscillations		G, A			
Norms for admitted performance loss due to oscillations (Goal for F2)		A	G, A		
Gap between norm for admitted and actual performance loss due to Oscillations		A	G, A		
Causes of the gap between admitted and actual performance loss due to oscillations		G, A			
Experiences with anti-oscillatory measures		G, A			
Problems and needs of the management of F1 Activities	G, A		G, A		
Proposals for innovation made by F4			A	G, A	A
Desired goal for F1 based on proposals for innovation			G, A		
Gap between desired and current goals of F1			G, A		
Required Capacity for reorganisation of F1 Activities			G, A		
Gap between required and actual capacity for reorganisation of F1 activities			G, A		
Reviews by F3 of Proposal for innovation			G, A	A	A
Finalized plans for adaptation of organisational goals (A joint F3 and F4 product)			G, A	G, A	A
Regulatory measures to counter imbalance between F3 and F4			A	A	G, A
Developments in the relevant environment of the organisation				G, A	
Norms for balance between F3 and F4					G, A
Actual imbalance between F3 and F4					G, A
Causes of imbalance between F3 and F4					G, A
Experiences with regulatory measures to counter imbalance between F3 and F4					G, A

Table 9: Generating and applying domains of knowledge Achterbergh and Vriens (2002; p.236)

G= Generating A= Applying

According to the literature review of this thesis, studies that relate to knowledge management from the viable system perspective skip to deeply focus on the process of knowledge sharing, both empirically and theoretically. What has been presented refers to general theoretical arguments. This might be due to the fact that researchers tend to think of knowledge sharing as a network phenomenon within the group/team and organisation, and so they have extensively applied the concepts of social network analysis (this is evident from the volume of literature in Section 2) and to a smaller extent the concept of team syntegrity. On the other side, procedures to deal with directly relevant social aspects of the knowledge sharing process based on the viable system model have not yet been developed. Researchers are still unfamiliar with the strengths of the systems approaches and methodologies (Edward et al, 2009), including the viable system model which can assist in the design and development of new and organic systems. Further, some systems' researchers consider the viable system model as a mechanistic and functionalist approach (Ulrich, 1983; Flood and Jackson, 1991) which is not very suitable for research on the process of knowledge sharing. However, there are studies developed in systems thinking literature which adopt interpretivist approaches (e.g. Espinosa and Walker, 2017, 2011; Espinosa et al. 2008; Espejo and Harnden, 1989), or even the emancipatory perspective (Ho, 1997), towards the viable system model. This might possibly illustrate why the viable system perspective of the knowledge sharing process is missing in the literature.

The following section will sum up all sections of the literature review and provide the comprehensive view of the research, considering a combination of VSM and SNA specific to the context of the action research that it pursues and seeks to implement.

2.4. Section 4: Reflection on Section 1, 2 and 3

This section reflects on the literature review provided in Section 1, Section 2 and Section 3. The relevant literature on the context of the research will then be provided, which is where the relevant research gaps for this thesis reside. An illustration of the action framework and the research questions for the present thesis will then be put forth.

Reflecting on the literature, it can be argued that knowledge has often been overlooked as something explicit that can be codified and that the knowledge can be disseminated without any problem. However, the breadth of knowledge taxonomy, which also includes a tacit element, suggests considering the tacit-explicit dimension of knowledge when dealing with complexities involved in the knowledge sharing projects.

For this thesis, which relates to sharing maths knowledge, the researcher adopts Polanyi's (1962) suggestion at the micro level of individual learning. Polanyi advocates examining the tacit-explicit dimension of knowledge in three phases, namely "ineffable", "intermediary" and "sophistication" (p.87). In this view, the relation between tacit and explicit refers to the dynamic interplay between thought and speech. Such a relation diverges from one end (i.e. ineffable) where the tacit prevails over the explicit, to another end (i.e. sophistication) where tacit and explicit disintegrate. This relation, however, does pass through an intermediary stage where tacit matches with the meaning of speech.

Using this perspective, Frade and Borges (2006) assert that the lack of connection between learners' expressions and their original comprehensions is directly associated with the way in which the tacit element can structurally couple and cooperate with the explicit element. Therefore, the dynamic interplay between the tacit and explicit elements of knowledge becomes important for the process of expression/articulation within the conversations. According to the above authors, the occurrence of a mistake/error in a learner's response to a maths problem-solving task does not essentially mean that he/she does not know the right answer nor that he/she has not internalised a specific type of knowledge. It instead may indicate that when articulating his/her understanding, the learner could be rather in the ineffable or the sophistication phases. If in the ineffable phase, then the learner's tacit understanding/comprehension is yet under construction. This shows the tacit prevalence over the explicit and leads to a learner's unclear expression/utterance in his/her answer, meaning that not enough evidence, clues or signs are provided to show understanding. If the learner is in the sophistication phase, then his/her tacit dimension of thinking might have been obstructed because of communication incompetence. This means that the learner's symbolic and representational operations are under development and are not yet ready for articulating/expressing his/her understanding. In this case, there will be imprecision or even contradictions in his/her expression of the answer, though his/her expression is made confidently.

However, risky interpretations are involved in the identification of a learner's phase/mode of operations. It is also important to acknowledge that such interpretations are subjective to the observers. The learner himself/herself does not necessarily have direct access to his/her own phase/mode of operations or its account of description.

A second-order cybernetician, who studies the process of learning as an interplay between the tacit and explicit elements of knowledge, would require a higher level of reflection, evaluation and inferences in order to identify a learner's phase/mode of operations. Such interpretations are different from more instant inferences (i.e. those in which the gap between the inferred and the observable is curtailed to the maximum). In effect, the interpretations that permit a second-order cybernetician to identify the learner's mode of operations are underpinned by his/her identification of sometimes fragmented evidence, signs and clues observed in certain aspects of the learner's understanding, although they are subtle in expressions, articulations and utterances. According to Frade and Borges (2006), there can be four phases of dynamic interplay between tacit and explicit knowledge within a process of learning, and they are: (1) tacit prevailing over the explicit; (2) tacit being on the edge of explicit; (3) tacit matching with explicit; and (4) independency of tacit and explicit. A second-order cybernetician can then take the understanding and insights regarding these stages into account when designing learners' knowledge management activities. These activities include support processes such as social communications/interactions. Lerman (2001) argues that:

> *"Children become mathematical by getting used to what counts as being mathematical, which is constituted in the social practices of the classroom. This may be a more fruitful way of speaking about learning, in which learning is about speaking, about how to speak in the legitimated codes of school mathematics" (p.50).*

Frade (2004) refers to the cooperative interplay between thoughts and speech as a social practice. She asserts that social communication is an act of knowing which is essential when it comes to generating mathematical knowledge. Hence, encouraging social communication practices and knowledge sharing plays a critical role in learners' development.

At the macro level, where knowledge management and learning activities are designed, this thesis adopts social interactions, communications, and engagement practices that are found in the community-based approaches (e.g. Wenger, 1998, 2000; Wenger et al., 2002). This is because, as Leistner (2010) justifies, it is very difficult to manage knowledge, since it is present merely in the mind of individuals and is affected by their prior experience (p.4). Social communications/interactions and engagement practices not only assist individual learners in learning and internalising the maths knowledge, but also give them access to new conceptual knowledge of maths expressed by other individuals. According to Spinuzzi (2015) and Leistner (2010), the social dynamic in communities highlights the success of knowledge sharing. Leistner (2010) clarifies that we can manage knowledge flow, stating that:

> *''you can enable a flow by creating an environment that people find safe, attractive, and efficient, and that motivates them to share their knowledge … to re-create knowledge in their own frame of reference'' (p.10).*

Leistner (2010) further asserts that managing the flow is:

> *"much about creating conditions that will make sharing more likely as it is about trying to have a direct influence on people'' (pp.17-18).*

In this arena, the technicalities of creating a thriving environment and implementing structures that (1) persuade people to share their knowledge with those who need it, and (2) support knowledge seekers to find the right person to refer to at the right time, are also significantly important. Although Spinuzzi (2015) and Leistner (2010) argue that technical implementation is not a repository of knowledge, a counter argument can be justified based on the context and purpose of knowledge sharing activity. Here, when we shift the boundaries, two nested layers of knowledge emerge. The first layer represents the primary conceptual content knowledge that an organisation wishes to be shared among its operational teams and individuals. The second layer illustrates the knowledge of those (e.g. change agents or managers) who strive to manage the process of knowledge sharing in the first layer, by, for instance, creating specific structures and a facilitative environment. It is evident that the technical implementation being hidden might not be of much use and is being taken for granted for the first layer, but for the second it is known as know-how and can be considered as a repository of knowledge in the mind of the second layer's knowers (e.g. managers, change agents). It is therefore the scope and level of knowledge sharing that would determine whether technical implementation can be classified as a repository of knowledge or a repository of information, or even, as Leistner (2010, p.115) puts it, as a "repository of pointers to those who know".

In this vein, an organisation does not tend to and cannot force its individuals to remain in a specific layer. Crossing the boundaries of the layers is part of dynamism in organisational, managerial and leadership development. Since organisations resemble a network of individuals (and their knowledge) working cooperatively together, they accumulate different types of knowledge and experience continuously. It is therefore argued that the technicalities around what is needed and how to structure a network of individuals (e.g. through teams with a specific structure) in order to improve the likelihood that knowledge seeker and knowledge acquirer discover each other at the right time, have a great chance of being regarded as a repository of knowledge. Within this purposefully-built knowledge sharing space and environment, "the repository of pointers to those who know", along with other types of knowledge in the fluid and complex mix, would also be socially constructed in the mind of individuals. Such an environment facilitates discussions, social interactions, and direct contacts which are regarded as mechanisms by which more of the tacit and experiential knowledge can be shared.

The next critical point is about how to measure and analyse knowledge sharing. While the literature review suggests using social network analysis, it would be simplistic to only rely on network measures in terms of numbers and quantities. Numbers indeed may not be able to portray the facilitated connections within the social network of knowledge or in a community of learners. Non-numerical measures are more indicative of potential knowledge flow, but not the direct quantification. Feedback indicators such as value, culture, quality, participation and skills development are of a non-numeric nature and tweak the inter-subjectivity of knowledge sharing activities. Performance improvement can also be a strong indicator of knowledge sharing in teams and in organisations and can be assessed both qualitatively and quantitatively. In fact, a mixed method would bring to light a series of emerging outcomes that are nearer to the reality.

This viewpoint on knowledge, knowledge management and knowledge sharing is more prevalent given the aim of this thesis, which attempts to design and build a socio-technical network space and collaborative structures in which people would feel free and stimulated to share their experience and knowledge. To design, develop and build such a space and structures for knowledge sharing activities, with knowledge as the main ingredient, being fuzzy, complex and a fluid mix, the complexity management and system thinking approaches are much more suitable than linear solutions.

The literature review on complexity management and systems thinking shows that the viable system model is a powerful tool for systems design as well as managing complexity and performance measurement (Espinosa and Walker, 2013), whilst it also has a greater potential to provide an optimal model for the discovery of knowledge sharing structures and processes in the organisation. This is because the viable system model can specify the necessary and sufficient preconditions for the viability of any organisation (Beer, 1985). In addition, the viable system model has been empirically tested and proven to be a reliable orientation tool for the design of an organisation and its activities, as well as a tool for diagnosing organisational problems in order to strengthen the organisation's adaptability, resilience, vitality, and development of potentials (Schwaninger and Scheef, 2016).

As discussed in Section 2.3.3.1.5, the viable system model, as a well-known systemic tool for managing complexity, is also able to model how information flows throughout the communication channels (Flood and Jackson, 1991, p.92). The model highlights both existing and missing links in different communication channels (Nyström, 2006, p.523). Such detailed analysis of relationships among the components and structure of a system is not present in any of the other systemic/non-systemic models (Preece, 2013). Further, the viable system model does support the understanding of the variety unbalances in the joint undertaking of specific tasks and offers criteria for redesigning tasks in more effective ways (Espinosa and Walker, 2013). The viable system model is underpinned by cybernetic science, i.e. the science of steering the system towards meeting objectives through the studying of information flow as well as the controlling of actions (Heylighen and Joslyn, 2001). These features therefore make the viable system model a superior choice among all other complexity management methods and tools for this thesis.

With reference to the literature review and the discussion mentioned above, it is possible to argue that the design, development and implementation of knowledge sharing activities and an empowering networked space (community approach), as well as the management of concerned complexities involved in the process of knowledge sharing, can be supported by a combination of the VSM and SNA. The following section provides the details on how VSM and SNA can be combined.

2.4.1. Combinative Perspective of VSM and SNA on the Process of Knowledge Sharing

Although the literature review of this thesis reveals no single empirical study which has concentrated specifically on the process of knowledge sharing, neither from the VSM perspective, nor from a combination of VSM and SNA, the very few theoretical VSM studies on knowledge management can be inspiring.

Since it is individuals who share and create knowledge (Nonaka and Takeuchi, 1995), and organisations are comprised of individuals who work, practise, learn and share knowledge together towards organisational goals (Wang and Noe, 2010), an organisation can be considered as a “knowledge network” (Yang and Yen, 2007). Knowledge is therefore shared and spread from the individual level to the group/team level and to the organisational level. Yang and Yen (2007) use an ontological lens to map the nature of knowledge onto the structure of VSM. They argue that since system 1 consists of units and divisions within which individuals are carrying out organisational tasks and activities and are pursuing viability in the organisation, the knowledge of system 1 is individuals’ knowledge. They refer to knowledge in system 2 as group/team knowledge which is effectively shared/common knowledge as well as an interface between individuals for coordination and anti-oscillation. Organisational knowledge is then distinguished based on its relevance to governing and controlling internal stability of the organisations (knowledge of system 3), strategic alignment with the environment (knowledge of system 4), as well as vision, identity and future development for the organisation (knowledge of system 5).

The interconnections in structural components of VSM are believed to systemically provide an optimal model to uncover and then to help the elimination of the structural holes in the networks of knowledge and therefore facilitate the emergence of shared knowledge. The rationale of this argument relates to the critical positions and statuses that some individuals in the knowledge network have. In fact, if these individuals bridge the holes in the network structure through linking the disconnected individuals or isolated groups/teams, they can help the effective flow of knowledge in the organisation (Burt, 2000). For instance, knowledge brokers and boundary spanners in the network play significant roles in sharing knowledge with a network. It is important to study the network positions and then to explore the ways in which organisations can effectively influence those taking such positions.

Apart from structure, VSM also has other distinctive features which appear to be very helpful for understanding the process of knowledge sharing. The first feature relates to the concept of variety engineering. Similar to the arguments on the viable system perspective for the so-called “knowledge management” mentioned by Leonard (2000) and Yang and Yen (2007), the process of knowledge sharing can benefit from the application of Ashby’s (1956) law of requisite variety. In this arena, variety engineering can be considered as a generative mechanism which creates unique opportunities and arrangements in the system so that social agents can collectively, and in a self-organised manner, steer and manage the complexities towards the identity, goals, and objectives of the system (Heylighen and Joslyn, 2001).

Since this research aims to design and implement the knowledge sharing activities and an encouraging networked space (community approach), such a generative mechanism would be required at both emerging layers of knowledge (i.e. in the primary activities layer and in the organisational/managerial layer). In addition, it can be argued that the mechanism of variety engineering has the potential to maximise shared knowledge in an organisation.

In the organisational/managerial layer, variety engineering focuses on a balance of variety amplification and variety attenuation to enhance effective management. Variety amplification in the process of knowledge sharing can be through facilitating the internal social interactions throughout the social network of knowledge, which in turn increases individuals and collectives' knowledge capabilities in the system. Since social interaction and engagement is a means of learning and sharing tacit and experiential knowledge, this model of facilitated learning has enough power to turn a social network of knowledge into a "community of practice" in which knowledge capabilities and operational tasks are integrated and become inseparable (Botha et al., 2008). In fact, this is why knowledge sharing networks are often described as communities of practice (Verburg and Andriessen, 2011). Through integrating knowledge capability into tasks, organisations' primary operations can increase their variety (Leonard, 2000; Yolles, 2000; Achterbergh and Vriens, 2002). In addition, since organisational tasks are interrelated and individuals are working on tasks in groups/teams within divisions, the increase in variety is also achieved through collaboration within and among operational groups/teams. Evidently, this form of variety relates to a type of knowing (knowledge) which captures the inclusive breadth of the knowledge domain embodied in a group/team (Walsh et al., 1988) and increases individual and team learning. The amplification of groups/teams' knowledge variety leads to improvement in the effectiveness of the solutions that a team may generate in response to problems that come from the environment and therefore it enhances the adaptability of the system (Gray, 2000). Varity attenuation in the process of knowledge sharing can be through supportive controlling and reviews of the primary activities and facilitation of goal orientation as well as management decisions with regard to focusing on specific problems in the environment rather than many. Further, homeostasis, i.e. a dynamic balance between stimuli (problems) and responses, can be undertaken through dynamic distribution of resources in an organisation, including knowledge assets, based on which knowledge is effectively shared and problems are solved through skill development, thus improving performance. In this light, knowledge sharing can be considered as a form of variety handling/complexity management that results in the generation of new knowledge.

Another key strength of VSM is the non-hierarchal management structure of the organisation (Espejo et al., 1999), and that it can be used to create implications from the social network perspective. Organisations' knowledge networks are formed through structural and relational ties and rely on cognitive dimensions to facilitate the process of knowledge sharing (Kankanhalli et al., 2005; Nahapiet and Ghoshal 1998). This process, therefore, can benefit from the embedded features of social networks. Knowledge sharing networks are set up inside as well as across organisations and require effective management. This is particularly pertinent to the research on knowledge sharing, where non-hierarchical management structures can facilitate the management of structural ties and assist with bridging the structural holes in the system. Critically, in fact, a top-down organisational structure is a major barrier to knowledge sharing, whereas a less centralised organisational structure is facilitative (Sharratt and Usoro, 2003) and provides an encouraging open space environment among social agents (Jones, 2005), strengthening relational ties. The weak ties reveal the structural holes in the system and are considered as non-redundant connections. They can be used for sharing non-redundant knowledge (Perry-Smith, 2006) to facilitate the movement of much needed knowledge resources, therefore enhancing individuals' performance (Burt, 2000) and specialisation (Gray, 2000). Moreover, when trustworthiness is controlled, weak ties, as Levin and Cross (2004) suggest, are more suitable for the knowledge recipient than the strong ties. This is perhaps due to personal characteristics, as well as the space and distance which knowledge recipients sometimes wish to keep from others. According to Hansen (1999), weak ties delay complex knowledge sharing but are useful for sharing less complex knowledge. This might be because of extra efforts involved in sharing complex knowledge, with individuals connected through weak ties perhaps not willing to go the extra mile. However, weak ties in sparse networks are signs of more network heterogeneity (Galunic and Rodan, 1998). When weak ties take over, innovation and novelty emerge. On the other hand, according to Granovetter (1973), strong ties create a team's synergy for remedies. In addition, and as Espinosa et al. (2002) reveal, said ties can lead to knowledge redundancy, as well as intellectual surplus in the context of knowledge. It is evident that weak and strong ties may both affect knowledge sharing, although in different ways. Within this scope, it will be interesting to understand the underlying mechanisms through which each of the differing social network ties can help in sharing the knowledge. In particular, since system 2 in VSM is recognised for its coordination, conflict resolution and anti-oscillation, it will be beneficial to investigate whether and how the tie strength, as well as network cohesion, can change over time in a viable system.

In the primary activity/operational layer, knowledge variety and knowledge overlap are crucial for team effectiveness (Hoopes and Postrel, 1999; Walsh et al., 1988; Rulke and Galaskiewicz, 2000). Knowledge variety is a range of different types of task knowledge in a team. In fact, the overall breadth of knowledge domains is captured through knowledge variety (Lyles and Schwenk, 1992; Walsh et al., 1988; Wong, 2008). Knowledge overlap is the extent of common task knowledge that team members possess (Wong, 2008). In this vein, possessing varied knowledge repositories advances team effectiveness, as it provides more combinatorial possibilities for dealing with complex problems and constructing creative solutions (Hargadon, 1999; Wong, 2008). In addition, it assists with a more effective analysis of the problems (Gray, 2000) as well as a more accurate understanding of the environment (McNamara et al., 2002; Wong, 2008). Therefore, it leads to more accurate solution design within knowledge-intensive teams (Bantel and Jackson, 1989) and enhances organisations' adaptive abilities (Gray, 2000). Further, it strengthens knowledge flow and knowledge sharing processes within the organisation (Gray, 2000). Knowledge overlap, as Hoopes and Postrel (1999) and Mark et al. (2000) argue, does represent the extent of shared knowledge (out of this range of knowledge varieties) as common knowledge in teams. It can be argued that these two dimensions of knowledge sharing processes can co-evolve concurrently. Wong (2008) draws from the theory of structural social capital to study how knowledge overlap and knowledge variety affect the internal and external advice support network structures. Knowledge support networks facilitate the performance by improving knowledge outcomes in terms of skills and capabilities that are developed in the process. According to this study, improvement in knowledge outcomes, and in turn in performance, is significantly associated with knowledge variety.

While increased knowledge diversity through knowledge variety is crucial when it comes to teams' performance and effectiveness, beyond a certain limit, further knowledge diversity is futile. In emergent teams, self-governance mechanisms are developed so that knowledge variety is increased in line with the response to the features of the complex problems that they are trying to solve. It is therefore unlikely that knowledge variety will be increased beyond what is practically useful for the task or activity (Gray, 2000). In addition, unlimited knowledge diversity is not what an effective team needs. In fact, too much knowledge variety may complicate a team's processes. This is because, with an increase in knowledge variety, the amount of coordinative effort needed to facilitate members and activities would also have to increase (Brooks, 1982). Further, according to Cohen and Levinthal (1990), with an increase in knowledge diversity, team members' ability to communicate might be reduced, which would limit the collaborations, especially if there is not a common point of reference.

In order for this research to design and develop a systemic methodology for the process of knowledge sharing, using a combinative perspective of VSM and SNA, an interesting context arises, where the primary activity of the system is "knowledge sharing and collaborative learning in teams". An example of this case can be found in a peer-assisted learning and practice classroom which represents a community of learners. This perspective has the potential to uncover the structure and mechanisms specific for the process of knowledge sharing and can be investigated using domains of viable knowledge offered by Achterbergh and Vriens (2002), which are linked to the performance of the system, and so the viable system model can assist with performance measurement.

The following will discuss relevant literature on knowledge sharing in the context of a university – which serves both as a knowledge organisation and as a community of learners.

2.4.2. Research Context: Knowledge Sharing in the Network of Learners in a University

A very recent review of knowledge management and knowledge sharing literature shows frequent reference to the knowledge organisation, knowledge workers and knowledge economy. This provides evidence regarding the crucial role of knowledge in modern society (Gamlath and Wilson, 2017). The lifeblood of knowledge organisations is knowledge workers, whose cognitive skills are employed to continuously create, integrate, and share the related knowledge with the relevant people at the right time (Arthur et al., 2008; Bennet and Bennet, 2004; Leon, 2011). In turn, the knowledge economy is driven by these knowledge organisations, which incorporate intellectual capital during all stages of product and service provisions (Powell and Snellman, 2004).

In this vein, universities are considered knowledge organisations which create knowledge through research as well as through disseminating knowledge via teaching and research publications (Fullwood, Rowley and Delbridge, 2013). Knowledge organisations support and promote the process of knowledge sharing among different stakeholders. Most knowledge management studies relate to individual-to-individual knowledge sharing or knowledge sharing among employees of an organisation. In the same trend, knowledge sharing in universities reflects the extent of studies on knowledge sharing among academics (e.g. Fullwood et al., 2013; Skaik and Othman, 2015; Tan and Md. Noor, 2013), though in practice universities have mechanisms to share knowledge among many and varied stakeholders.

Although a university is a natural ground and an ordinary context for learning, there is scarce research on student-to-student knowledge sharing in universities (Gamlath and Wilson, 2017). The very few studies that exist only use survey questionnaires to investigate students' knowledge sharing behaviour (e.g. Chin Wei et al., 2012). This shows that research exploring other methods of knowledge sharing between students is very limited.

In addition, the major cuts in public funding for HEIs has led to the batch process approach in university teaching. Hence, lecturers have to teach and manage a large number of students. The face-to-face contact hours have also been reduced. The lecturers and teachers are focusing on blended and online methods of teaching, for which some of the learning materials are being put online and on e-learning platforms (Gamlath and Wilson, 2017). Such online teaching and learning methods reduce the chances for students to interact and engage with the lecturers and with each other on a face-to-face basis. Online interaction mechanisms on e-learning platforms in the universities are also not popular for students.

While tacit knowledge can only be shared when individuals are socially engaged in learning activities and face-to-face interactions, there is an urgent need for the utilisation of intellectual capital through approaches which complement the current lecturer-to-student tradition. In this arena, one of the key educational deployment approaches can be knowledge sharing through student-to-student methods in universities.

Although knowledge management literature is heavily focused on knowledge sharing between members or employees of an organisation, in a university context the word "member" does not constitute students. Universities are not ready to consider students as members. Despite this, however, based on the literature, the important role of internal and external stakeholders and the role of the environment in members' learning and experiential development, as well as the role of members' engagement in the creation of knowledge and the knowledge sharing process, are well-known and well-researched (Gamlath and Wilson, 2017).

This is partly because universities are part of the service industry and students are considered as major recipients of educational services. Universities in fact tend to view students as customers. Bejou (2005) relates to the marketing approaches for managing customer-supplier relationships with students in order to deal with students' experience at university in different stages and to establish a pleasant continuous transaction between students and the university. According to Tight (2013), mass production in educational settings, cost reductions, greater attention to quality improvement and the heavy competition between universities to attract more students are evidence which supports the argument for students to be viewed as customers of the universities. In addition, corporate policies have also found their way into universities. Although greater focus on satisfying students' needs has been achieved, said client/customer approach is still unable to rightfully capture the core of this unique relationship (Svensson and Wood, 2007).

Nonetheless, students and lecturers have diverse opinions on whether to treat students as customers and whether viewing students as customers has a positive influence on the quality of education and educational service delivery (Koris et al., 2015; Watjatrakul, 2014). This is because students are openly volunteering to be ambassadors of their universities and some graduates are generously donating funds or serve on the boards as well as partaking in promotional events (Monks, 2003).

Upon reflection, this research avoids the client/customer perspective on students. The prevalent view of this thesis is to consider students as co-creators, collaborators or co-producers of knowledge through knowledge sharing and learning (Bovill, Cook-Sather and Felten, 2011; Carey, 2013). This view considers students as an integral party for the knowledge sharing activities in the learning environment of universities.

The collaborators view has been introduced in universities from a perspective of students collaborating with teachers to design courses and evaluate the assessment methods. This perspective reveals a transformational approach to teaching and learning, thus illustrating the interdependence between students and lecturers (Fielding, 2004). This approach not only facilitates the development of students' teamwork skills and professional capabilities, but also provides an environment in which students become proactive in their learning process rather than being just passive knowledge recipients (Giles et al., 2004). Said approach also assists in diminishing the psychological distance between teachers and students, thus enabling students to have a sense of ownership for their learning (Freeman et al., 2014).

With VSM as a systemic model and its non-hierarchal open space settings for collaborative work as well as its bottom-up approach, it is argued that VSM can consider students as being included as members of HEIs and as the focal intellectual capital of their knowledge network. A university is in fact considered as a community of learners. Overall, it appears that no attention has been paid to the main purpose of academic knowledge sharing among students, i.e. their academic learning in the university using student-to-student approaches. VSM has the potential to maximise students' knowledge sharing through collective learning, skills development and academic performance improvement. The synergetic nature of actions based on VSM through mechanisms such as self-organisation has a great potential to provide an embedded networked context within which thoughts, learning and actions come together to increase students' involvement in the naturally-occurring critical inquiries, and encourage them to think creatively and to develop new initiatives. In contrast, according to Levin and Greenwood (2001), traditional methods represent the divorce between thoughts and actions and are only a rehearsal of knowledge provided by teachers in a one-way communication. Such a traditional method does not satisfy the skill requirements of the future employers.

In this arena, VSM can also help at the management level, to provide an ongoing scan of, and an analytical understanding of, the outside environment. Hence, it can be far better when it comes to assisting in designing and implementing agile strategies towards organisational resilience and development, in terms of students' employability as well as the university ranking. This is an important feature of VSM – distinguishing systemic methods of learning and teaching from traditional approaches.

While there is an evident call for deep research investigations on various ways and aspects of knowledge sharing processes among students (Gamlath and Wilson, 2017), the literature review of this thesis also reveals the extreme scarcity of research on processes of knowledge sharing from the VSM perspective as well as from the combinative perspective of VSM and SNA. In addition, according to Pagano and Paucar-Caceres (2013), there is little account of research using systems thinking to address education management or management of learning.

In this arena, the urgency of the call for systemic and soft-OR approaches in managing education and learning in universities is further evident. This is because educational performance in HEIs (in terms of both quantity and quality) requires a variety of resources and the current cost cuts in public funding are pressing hard for efficiency (Johnes et al., 2017). However, performance management in terms of assessing teaching and learning in HEIs is complex and needs careful consideration on both subjective and objective matters (Thanassouli et al., 2017). It is apparent that linear and hard-OR approaches have failed to perceive both the quantity and quality of education in their measures of performance management in HEIs. According to De Witte and Lopex-Torres (2017), the linear hard-OR perspective of performance management sees universities as knowledge production factories with inputs, processes and outputs. They argue that hard-OR researchers find that the way in which production technologies (the production technologies that are used by students to gain knowledge) are defined and estimated is very complex. They also state that researchers are widely using Data Envelopment Analysis (DEA) to assess educational efficiency in schools and universities. In this regard, Mayston (2017) argues that the causal assumptions of existing technology and the possible knowledge production associated with that might not held. This can be the case when performance evaluation is comprised of measures for quality assessment. DEA in this scenario will therefore overestimate the scope of improvements in efficiency and underestimate the significance of improvements. The above author then calls for allocative efficiency evaluation methods and tools that are outcome-orientated.

Recognising these problems, the call for systemic methods and tools is paramount. With a combinative perspective of VSM and SNA, the present thesis is a step in this direction, aiming to design, develop and implement a systemic multi-methodology for the process of knowledge sharing to support students' individual and team learning and performance improvement. The case study of this operational research relates to the processes of knowledge sharing and collaborative learning among students in a university in the UK. The students in this study are those who have been freshly admitted to the university. All of these students had to take a compulsory module of Academic and Professional Skill in their first year to build their required quantitative and qualitative skills. The focus of this research revolves around the quantitative part of the module where most of the issues and performance problems were initially identified.

2.4.2.1. Knowledge Sharing: Facilitated Learning and Development

The outcomes of knowledge sharing processes are believed to manifest themselves in many and varied ways. Senge (1990) reveals that sharing and acquiring knowledge might not be sufficient in terms of organisational survival in times of change and competitions. It is necessary to also develop and improve the learning capabilities. Knowledge sharing and learning appear to complement each other in terms of the system's effectiveness. In addition, since this thesis revolves around management science and the chosen context is a HEI, it therefore relates to the concept of learning as well as learning management. The literature on the pedagogical and psychological perspectives of learning, however, is not in the scope of this research but the management aspects is.

In this vein, and in line with the arguments in Section 2.3.2, the purpose of a knowledge sharing system is not necessarily an intrinsic feature of it but substantially a specification that can be set by the researcher, or change agent, who is working on the developmental perspectives of the system. For this study, the researcher does not want to take a top-down intervening role from outside, but rather the researcher becomes an internal facilitator and assists the participants in developing the system's purpose based on their own wills. It is about facilitation to orient and converge different views towards a consensus. This can be aligned with the school's aim to enhance the skills and capabilities that effectively influence the learning and improve the performance. The following is an exploration of key concepts in the arena of facilitated learning and development in a community of learners.

2.4.2.1.1. Individual, Team and Collective Learning

It is important to first look at what is meant by "learning". While there is no general agreement in the literature on defining the term, Dodgson (1993) relates to learning as a process by which an organisation creates, enhances and organises knowledge in the routines of activities surrounded by its culture. This approach to learning relates to improvements in peoples' skills and consequently to the adaptive capacity as well as the development of organisational efficiency. Smith (1999) views learning as a process of transformation in the way of thinking and behaving, as well as fulfilling potential and the increase in capacity for action in the communities. Learning has also been perceived as a sense of organisation that detects and corrects errors/mistakes (Argyris and Schön, 1978). Argyris (1993) places emphasis on two mechanisms that lead to learning in an organisational system. First, learning occurs upon accomplishments of goals in such a way that actual results match with the intended outcomes. Second, learning happens upon a mismatch between intention and results, and leads to detecting and rectifying the mistakes in an effort to re-match the mismatch.

Learning can be studied at different levels, i.e. individual, group/team, organisation and inter-organisation (van Winkelen, 2010). Examples of such studies in the literature are Holmqvist (2004) on individual learning, Brown and Duguid (2001) and Lave and Wenger (1991) on group/team learning, Jerez-Gómez et al. (2005) and Weick and Roberts (1993) on learning in organisations, and Araujo (1998) and Dyer and Nobeoka (2000) on inter-organisational learning. In the arena of individual learning, Simon (1991) argues that it is only individuals who can learn. In this view, an organisation is a collection of individuals who learn and therefore the aggregate of individuals' knowledge resembles the organisation's knowledge. This transactional cost model towards knowledge management contends that new knowledge can be obtained through bringing in new people who possess such new knowledge. Beesley (2004) asserts that learning spreads from the individual level towards the organisation level. In effect, it will not ensue in a level if it has not occurred at its previous level. Argyris (1993) states that the actions performed by individuals result in learning in the organisation.

Figure 6: Spread of Knowledge and Learning and Importance of Groups/Teams – modified version of Beesley's (2004, p.79) Model

According to Nonaka et al. (2000) and Wang and Ahmed (2003), learning relates to interactions between individuals in the organisation as well as the interactions between the organisation and its surrounding environment. This socially-situated learning in the organisation is in agreement with the resource-based view.

In addition, significant to social interactions is social capital, i.e. the resources that are features of networks of social relations. Social capital is a critical part of intellectual capital in the organisation. In order to understand the link between intellectual capital and social capital, Nahapiet and Ghoshal (1998) provide three dimensions, namely structural, relational and cognitive. The structural dimension, according to Burt (1992), relates to the configuration of connections among individuals or organisational units which are definitive in shaping the patterns that link individuals in terms of whom they can reach out to and how. The relational perspective refers to personal relations built upon previous interactions (Granovetter, 1992). The cognitive dimension refers to resources that offer a shared sense, meaning and interpretations between individuals represented in common languages, rituals and codes (Arrow, 1974), as well as shared stories of events (Orr, 1990).

Bell et al. (2012) relate to team learning and emphasise that team learning processes are multilevel, dynamic and emergent. They provide a team learning cycle framework integrating the team's collaborative cognitions, knowledge & information processing as well as the team's regulations. The team's collaborative cognition refers to the decisions that are made in the team. Such cognition is dynamic and emerges through time (Klein et al., 2003). Intrinsically it includes knowledge building processes such as knowledge acquisition, knowledge sharing and knowledge adaptation in the team in order to solve complex problems (Fiore et al., 2010). Knowledge & Information processing relates to cybernetics control and feedback loops, as well as self-regulation (Wiener, 1948). Groups/teams are considered as information processors and their cognition and knowledge sharing are important factors for team learning (Wilson et al., 2007; Hinsz et al., 1997). The team's regulation focuses on group goal setting (O'Leary-Kelly, 1994), learning and development (Kozlowski et al., 2009), as well as action regulation, performance and productivity (Pritchard et al., 2008; DeShon et al., 2004).

In their analysis, Bell et al. (2012) show that the team's emergent positions include goal orientation, team efficacy, cohesion/conflict resolution and psychological safety. They also relate to team learning outcomes through collective knowledge, team performance, and the shared mental model.

One important feature of this framework is its multilevel property, in that the choice is not being made to separate individuals from the team, which would be seen as reductionist. It allows for individuals and the team to consider everything together in a more systemic way. This multilevel perspective also paves the way for implications of social interactions to emerge, which can be studied through the lens of second-order cybernetics.

2.4.2.1.2. Typologies of Learning Approaches

Argyris and Schön (1978) provide two types of learning, namely single-loop learning and double-loop learning. Single-loop learning refers to the process of sensing or detecting the mistakes and rectifying them. This process is required so that the system can carry on its current procedures and routines towards reaching its activity goals. The double-loop learning relates to the process of sensing or detecting the mistakes that revolve around modifying the goals, policies, norms, and ethos of the system as a whole and rectifying them. According to Argyris (1993), in the detection and correction of an error, if the system's values are not questioned, it is single-loop learning, no matter whether at individual, group, or organisational level. In his view, however, both types of learning are essential for the organisation because the daily routines are supported by single-loop learning and dealing with complex matters is facilitated by double-loop learning.

For Botkin et al. (1979), learning is of three types. The first is maintenance learning, which relates to uncovering better ways of achieving operational objectives in terms of know-how. This may mean doing incorrect things in the correct way. Maintenance learning, however, fails to acknowledge and consider the challenges arising from the changing environment. Hence, it does not suffice for problem solving in times of crisis. The second is shock learning, which refers to reactive actions towards the changing conditions. Yet, shock learning might create more issues than the problem which is supposed to be solved due to being under crisis pressure. Third is the innovative and anticipatory learning, characterised by being participatory and future-orientated. This type of learning covers the shortcomings of the other two.

For Senge and Fulmer (1993), there are two distinctive types of learning, i.e. instrumental learning and generative learning. Instrumental learning suggests that in dealing with changing circumstances, individuals and organisations adapt their behaviour (which is vital for survival). In comparison, generative learning is more about individuals and organisations' capability building through the essential change in their ways of thinking, in order to deal with possible problems in the future. This can be manifested through developing systems thinking capabilities in the organisation. Later, in 1997, Senge introduces survival learning/adaptive learning. According to Senge, this type of learning is learning from experience in order to react in the most suitable way to situations and to avoid mistakes and errors. While survival/adaptive learning is critical for organisations, however, Senge provides the example of Royal Dutch Shell in 1983 to show that this type of knowledge is not always sufficient for organisational survival and, therefore, it should be combined with generative learning.

With this exploration of learning typologies in management, it is evident that maintenance learning, instrumental learning and survival/adaptive learning are of the single-loop learning type. Innovative/anticipatory learning and generative learning are considered as double-loop learning.

With reference to the context of this research, i.e. the education domain, there also exists a number of learning approaches, such as inquiry-based learning, problem-based learning, self-regulated learning, facilitative learning, and collaborative learning. These methods can be employed at both classroom level and school level.

Inquiry-based learning as a constructivist approach permits construction of knowledge by asking questions, assessing the problems, carrying out investigation, collecting and analysing data, interpreting, and providing explanations and conclusions. This learning method can be cyclical. While the processes involved in this approach deal with varied thinking and learning capabilities, such as critical thinking, creative thinking, self-regulated learning, communication skills and meta-cognitive ability (Hmelo-Silver et al., 2007), said approach faces five challenges because of its design. The first issue is about how to motivate students to interact and engage in the approach. The second relates to the mastering of inquiry strategies by students. The third pertains to covering sufficient content of the subject. The fourth issue refers to management and coordination problems in the activities, whilst the fifth relates to practical obstacles, such as lack of technology (Edelson et al., 1999).

Problem-based learning relates to an approach based on which students attempt to solve real problems in small groups (Barrows, 1996). This method can use inquiry-based learning strategies (Li, 2012). Implementation of problem-based learning in an education system is difficult, particularly where models of transmission of instructions are pervasive (Tang and Shen, 2005).

Self-regulated learning focuses on a complex learning phenomenon that entails motivation, strategic thinking and meta-cognition (Schunk and Ertmer, 2000). Modelling self-assessment and task choices improve students' self-regulated learning skills (Kostons et al., 2012). In this approach, reflective thinking can be exercised through prompting questions (Lin, 2001).

Facilitative learning (Rogers, 1969) refers to the role that a facilitator plays in supporting the learning process (Rowley et al., 2018). According to Rogers (1969), facilitative learning offers three guidelines in order to steer and facilitate the process of learning. First, the facilitator assists in setting the climate of the classroom, which is required for creating the learning experience. This is achieved through helping individuals and teams to define and clarify their goal. Second, the facilitator lets the learners identify their own sensible and meaningful goals/objectives and purposes. This provides the motivation for extensive learning. The facilitator then provides the learners with access to a wide range of resources. The facilitator should also be flexibly available and consider himself/herself as a resource for the learners. Third, the facilitator considers both the intellectual (academic) and the emotional perspectives of the learning. He/she shares his/her own emotions and participates in the learning, whilst also recognising his/her own boundaries/limitations.

Collaborative learning pays attention to students' contributions in order to solve a problem in a learning environment (Teasley and Roschelle, 1993). In line with social constructivism, students create knowledge via social interactions (Atwater, 1996). It is evident that, to a great extent, collaborative learning is embedded in other learning types. It benefits students with cognitive and meta-cognitive outcomes. Yet, its success relies on conditions such as prior experience of group members, the group composition and the quality of subject elucidation (Janssen et al., 2010). The collaborative learning approach is not only an educational learning method, but has also been applied in the management field.

One way to reflect on the learning approaches mentioned above is to compare them with double-loop learning. This means to consider, in each of the learning approaches, the extent to which the main stakeholder of the system (i.e. students) can effectively question the governing policies, procedures, values and ethos of the system and can actually change them under that particular method. This is a matter of real self-concept and identity of students' learning in double-loop learning. In addition, when this issue is at stake, then the question is: how else would HEI institutions possibly consider students as members rather than service users of their institutions? These issues make a strong call for systemic approaches that encourage double-loop learning which empowers both learning and learning how to learn effectively by questioning the system's values and policies.

Aligned with the purpose of this research and the intended solution, the concept of learning would be viewed as "a process by which a system generates, shares, enhances, rectifies and organises knowledge in the problem-solving activities that are routines for skills and capability development and performance improvement". It is assumed that the efforts in knowledge sharing activities lead to fresh thinking, brainstorming and value judgement in both operational and management challenges, as well as in enhancing the system's capacity. This is enactment of both single- and double-loop learning.

2.4.2.1.3. Knowledge Sharing and Facilitating the Collaborative Learning

According to Rae et al. (2006), collaborative learning facilitates building new knowledge in order to achieve problem solving. It assists with recognition of the differences. It also offers support in dealing with complexities in the team or community. Bell et al. (2012) relate to collaborative learning through knowledge sharing in teams, based on which individual knowledge is shaped subsequently. Wu and Lin (2013) refer to the mediating roles that collaboration and learning orientation play, particularly in the process of sharing tacit knowledge. Bandura (1977) argues that collaborative learning saves time through getting help from others and reduces the costs. Pritchard et al. (2006) highlight the role of the team's generic and specific skills training and development in facilitating and enhancing collaborative knowledge sharing and learning.

Buckman (2004) states that the effectiveness of knowledge sharing relies fundamentally on the human network (and not on the information technology or information system). However, Soon and Fraser (2011) reveal that information technologies can be facilitative in collaborative knowledge sharing among learners. Although e-learning is already being used for this purpose and enables collaborative learning and blended methods in learning spaces, Gamlath and Wilson (2017) call for using specific technologies that facilitate collaboration among learners when they are not able to attend face-to-face, through online knowledge sharing spaces and platforms.

In the context of education, knowledge sharing and collaborative learning relate to a number of processes on a spectrum based on formality and informality. The formal processes are those that are planned, initiated and monitored by academic staff and are embedded in the structure of courses and module management. They are endorsed and funded as well as quality-checked, and are compulsory. The informal processes, in contrast, are those that are organic, grass-roots, initiated by students, and not monitored. They are promoted in the existing community of learners, unfunded, not quality-checked, and are voluntary. Examples of formal processes are in class group learning & assessment and staff-monitored discussion forums (online). On the other hand, informal processes include learner-organised study groups, learner-driven Facebook groups, and coffee conversations. There are, however, examples of effective knowledge sharing and collaborative learning processes such as peer-learning-assessing and staff-instigated discussions on social media that are in the middle of the spectrum of formal and informal processes (Gamlath and Wilson, 2017).

Kaye (1992) explains that collaborative learning is a process manifested through seven key features. First, in collaborative learning, although learning happens at the individual level, there are a variety of influential external factors, such as group's communications and interpersonal connections. Second, collaborative learning is a social process based on people's interactions. Third, power relations and group negotiations, as well as role exchange, matter a lot. Fourth, there is synergy in the collaborative learning which makes the whole greater than the sum of its components. Fifth, for occasional not successful collaborative learning, learning from mistakes comes about as a positive consequence. Sixth, collaborative learning can be through an organised learning group or reliance on support offered by others/to others. Seventh, the collaborative learning process is time-bound and therefore the help which is required would have to be adjusted to the duration of the process. However, Kay (1992) acknowledges that misunderstandings, disagreements and disputes can emerge in the collaborative learning, which will appear as a waste of time.

All of these rationalise the significant role that a facilitator can play in the process of collaborative learning. Rogers' (1969) facilitative learning approach supports student-centred learning, in which the academics take a facilitative role to support students' learning process. However, according to Rogers (1980, 1989), the power balance is an important issue that would emerge because of the shift of control from the lecturer to the collective of learners. Such a shift has a great influence on the learners, the lecturers and the education administrators. Ashwin et al. (2015) discuss how higher education has recently started to recognise the advantages of student-centred learning (also known as student-led inquiry). This method enables greater student interaction and permits learners to take charge of their own learning. Vygotsky (1978) also emphasises the facilitating role of the teacher. He recognises the teacher beyond merely a knowledge-transmitter. According to Rogers (1969), the teaching role in this approach depends on the process of learning instead of the static knowledge. In particular, the self-initiation and self-assessment that occur in the learning process are critical characteristics that sum up the quality of the involvement of the learner.

With reference to Rogers' (1989) elucidation of politics of power, McCabe and O'Connor (2014) report that the current orthodoxy still feels threatened by student-led learning based on facilitation theory, though teachers are being encouraged to discover possible ways to alternate the traditional teaching approaches with student-centred learning methods. Learners who have not had previous student-centred learning experience might also be confused with their expectations about teachers' teaching/facilitating approach. In addition, Rowley et al. (2018) admit that adherence to the three facilitation principles offered by Rogers (1969) is difficult. However, with reference to discussion on the combinative perspective of VSM and SNA for the process of knowledge sharing (Section 2.4.1), it appears that implementing domains of viable knowledge can assist both learners and teachers (facilitators) in finding a way to fulfil the facilitation principles and pave the way towards student-centred learning and knowledge sharing.

2.4.2.1.3.1. Capability Development and Performance Improvement

Skills and capabilities are defined as an organisation's capacity to organise its resources jointly together (explicit and tacit knowledge), which are embedded in the processes (Wang and Ahmed, 2007). Skills are sometimes referred to as blocks of repeatable joint actions (Teece et al., 1997) as well as distinct, complex, guided and practised ways of performing activities (Helfat et al., 2007) which are transferable within the organisation (Teece et al., 1997). A capability is the potential and capacity to perform things, but it is not the tasks that are performed (Easterby-Smith and Prieto, 2008).

Capabilities emerge from, and rely on, purposeful knowledge sharing activities and collaborative learning processes (e.g. Eisenhardt and Martin, 2000; Helfat and Winter, 2011; Teece, 2007; Zollo and Winter, 2002) that encourage members' interactions in problem solving (Zollo and Winter, 2002). Vergne and Durand (2011) highlight the role of collective efforts in capability development. They argue that capabilities and skills are not the result of isolated members' actions but of social engagements among individual members for collective learning processes. This position is in agreement with Grant (1996) and Kogut and Zander (1996), who view capability development as being a result of collective learning.

A number of authors have called for establishing interaction-related theories of skills and capability development (e.g. Barney and Felin, 2013; Devinney, 2013; Winter, 2013). However, what is perceived in the literature so far relates to accounts of studies at organisational level (e.g. Kale and Singh, 2007; Teece, 2007) or at individual level (e.g. Helfat and Peteraf, 2015).

Although socialisation (Nonaka and Takeuchi, 1995) and task routines and procedures (Nelson and Winter, 1982) play great roles in the development and realisation of organisational skills and capabilities as well as in organisational learning, the literature is silent about linking individual capabilities to organisational competencies through the mechanism of social interactions (Bridoux et al., 2016). At the team level, the focus is placed on task knowledge. However, little attention is paid to social knowledge and social skills. In particular, social interactions play a significant role since, according to Senge (2006), learning teams would be able to constantly and more widely teach and instil knowledge and skills in other learning teams. According to Prichard and Ashleigh (2012), within teams also, the cycle of learning and working has turned into a more flexible form of operation in order to reach higher levels of skills, capabilities and knowledge. However, since capability development requires knowledge sharing through interactions, individuals might not be willing to work or engage with others in order to develop a skill. One reason might be that they perceive knowledge sharing as a costly behaviour to them (Husted and Michailova, 2002). Another rationale could be that they would be scared of other people's negative feedback (Catmull and Wallace, 2014).

In addition, Schreyögg and Kliesch-Eberl (2007) report that skills and capability development in large and medium size institutions is not the outcome of the top manger's arrangement. According to Dosi et al. (2000), this development is a bottom-up process that needs purposeful and intentional endeavours from the individuals who are going to use such capabilities. However, managers can play a key role in guiding skills and capability development (Catmull and Wallace, 2014).

Upon reflection, it is very interesting to observe that collaborative learning is key to the development of individual skills and capabilities (Helfat and Peteraf, 2015), as well as organisational skills and capabilities (Teece, 2007), but team skills are the means through which to enhance collaborative learning (Prichard et al., 2006). This signifies the importance and position of the team itself, as well as the skills and capability development at team level, in influencing skills development at both individual and organisational levels through its impacts on collaborative learning.

Further, since learning is a complex, dynamic and emergent process (Bell et al., 2012), it is essential to examine what type of dynamic capabilities emerge and how they can facilitate performance improvement in organisations. Wang and Ahmed (2007) define dynamic capabilities as an organisation's "behavioural orientation constantly to integrate, reconfigure, renew and recreate its resources and capabilities and, most importantly, upgrade and reconstruct its core capabilities in response to the changing environment to attain and sustain competitive advantage". They argue that dynamic capabilities are embedded in the organisational processes. Dynamic capabilities, according to Wang and Ahmed (2007), consist of adaptive capability, absorptive capability and innovative capability. Adaptive capability refers to the organisation's ability to recognise and benefit from opportunities in the environment (Chakravarthy, 1982) and to adapt to the changes and arrange its resources in order to manage the environmental demand so as to survive and remain viable (Teece et al., 1997). Adaptive capability manifests itself in terms of strategic flexibility (Sanchez, 1995) and is developed along with evolving organisational forms (Rindova and Kotha, 2001). It can be measured through assessing whether an organisation's management system motivates people to confront sacred cows and outdated practices, allowing the organisation to be agile towards changes in the external environment (Gibson and Brikinshaw, 2004). Absorptive capability relates to the ability of an organisation to acknowledge the value of knowledge, absorb it and employ it to achieve organisational goals (Cohen and Levinthal, 1990). It is therefore evident that density of knowledge can be used as a measure of absorptive capability in the organisation (Tsai, 2001). The more absorptive capability is depicted, the more dynamic capability is exhibited (Wang and Ahmed, 2007). Innovative capability focuses on the ability of the firm to develop new methods and design new organisational forms and services through arranging and aligning strategic resources and innovative processes. Measures of innovative capability are strategic innovative orientation, innovative processes and service innovativeness (Wang and Ahmed, 2007). While dynamic capabilities are necessary, the way and the context in which an organisation deploys and utilises such capabilities are important in enabling that organisation's success, and allowing it to reach its objectives to stay competitive. In this arena, there is debate on the relationship between capabilities, resources and routines (Easterby-Smith and Prieto, 2008). Helfat and Peteraf (2003) adapt to resources. Additionally, Zollo and Winter (2002) pay more attention to routines and procedures that make use of resources in actions or reconfigure them. In an attempt to respond to these issues, Winter (2003) provides a hierarchy of capabilities. Operational capabilities are at level 0, and focus on the routines and responsibilities of the organisation's effective operations. Dynamic capabilities at level 1 (first-order) relate to managing, controlling, altering and modifying the operational procedures. Easterby-Smith and Prieto (2008) reveal that operational capabilities are evidently outcomes of dynamic capabilities. Learning capabilities at level 3 (second-order) are those that support the creation, amendment and adaptation of dynamic capabilities (see Figure 7).

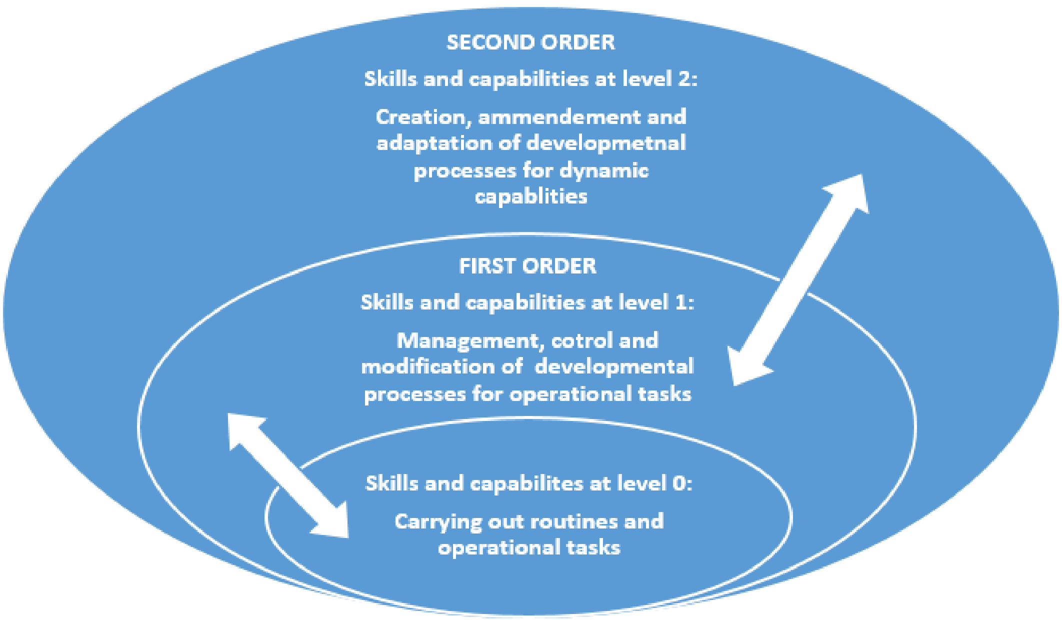


Figure 7: Creation, Amendment and Adaptation of Dynamic Capabilities – (adapted from Easterby-Smith and Prieto, 2008)

It is important to note that these levels of capability development are observer-relative. An observer develops operational skills at level 0, whilst carrying out the routine tasks. He/she can develop his/her dynamic capabilities by reflecting on his/her development process at level 0, which creates a feedback loop and is considered as a mechanism of learning. This takes him/her to skills development at level 1. A group of observers at level 1 can reflect on the capabilities that they develop at this level. They again create a learning feedback loop. This takes them to skills development at level 2. According to Easterby-Smith and Prieto (2008) there is a debate on the role of learning. Bowman and Ambrosini (2003) and Teece et al. (1997) suggest that learning is a specific kind of process underpinning dynamic capabilities which relate to repetitive tasks, conducting experiments and spotting opportunities. From the other side, Zott (2003) argues that learning about how to deploy the resources is an attribute of dynamic capabilities which is relevant to performance. Winter (2003) specifies that mechanisms of learning facilitate the development of dynamic capabilities. Zollo and Winter (2002) refer to dynamic capabilities as a result of learning, which in turn shape the operational capabilities. Upon reflection, learning itself may be seen as a dynamic capability of second-order type. Winter (2003) asserts that dynamic capabilities indicate development and change, and according to Zollo and Winter (2002) they exist in routines and procedures (including and in particular in high level processes) rather than merely in resources. Assessing the processes based on which an organisation learns is therefore deterministic in understanding the development and evolution of dynamic capabilities.

In the area of knowledge management, Easterby-Smith and Prieto (2008) argue that learning processes intervene and contribute to development in both knowledge management and dynamic capabilities. Based on Winter's (2003) grouping, these skills and capabilities that are developed will be of second-order type. In this vein, exploration and exploitation are recognised as critical learning processes (Easterby-Smith and Prieto, 2008; Zollo and Winter, 2002) in order to critique the existing boundaries and go beyond the current practices as well as to ensure that the outcomes of exploitation are considered as feedback in the assessment of underlying routines and procedures. However, in using these learning processes, a balance between the two has to be appropriately managed. In addition, according to Vera and Crossan (2003), learning processes influence and are influenced by building and setting a system for learning or learning infrastructures. Evidently, knowledge sharing processes pool in the social interactions and procedural knowledge and therefore provide the required infrastructures in order to facilitate the embedded learning and capability development. According to Zollo and Winter (2002), learning mechanisms such as accumulation of experience, communication of knowledge, and codification, can be organised at the operational level. At the organisational level, Orlikowski (2002) suggests that particular practices such as mentoring, training and rewards can be influential in skills and capability development.

In the arena of collaborative learning in the context of HEIs and in order to enhance learners' skills and capabilities, Jenkins and Walker (2014) suggest categorising the opportunities that are uncovered in courses and educational modules and lessons. Such endeavours can change the role and nature of the learner-tutor relationships towards more participative and collaborative learning modes. Learners therefore can engage more in vital learning processes such as detecting errors/mistakes, planning, and reviewing and evaluating their own as well as their peer learners' performance. The interaction and social engagements embedded in these activities further lead to recognition of the needs in learners' knowledge network and in developing personal qualities and capabilities. However, there is learners' commentary evidence showing that time limits of lessons and modules do not allow for effective assessment, feedback and reflection in order for the skills and capabilities to develop. In addition, the literature review shows that whilst HEIs enormously focus on development of skills and competencies that relate to graduate employability, the level and extent of skills and capabilities that refer to learning processes and learning how to learn, in the classrooms, are yet to be fully realised.

Through a reflection on literature mentioned in this section so far, the importance of routines and activity procedures is being highlighted in terms of the localities where skills and capabilities are germinated into life and are developed further at individual, team and organisational levels, as well as the importance of facilitating the embedded collaborative learning. This signifies the importance of routines/processes which underpin learning by doing as a substantial way of skills and capability development (which in turn leads to improvement in performance). In this vein, knowledge sharing and collaborative learning can also occur in action learning sets within communities of practice (Lave and Wenger, 1991) and other socially-situated contexts, and hence they are not exclusive to formalities such as accredited courses or modules and lessons in academic organisations. It is therefore evident that creating learners' communities of practice within HEIs (in dealing with complexities of knowledge sharing and learning) is underpinned by combinations of formal and situational learning, with people taking advantage of both in a complimentary way for the purpose of capability development and performance improvement. Therefore, despite the review of the literature on skills and capability development presented above, there still remains the need to explore action learning, experiencing and community of practice.

2.4.2.1.4. Action Learning, Experience and Community of Practice

Action learning literature owes its development to Revans (1981). He refers to action learning as a means of development (of intellectual, physical and emotional capabilities). In order to develop these skills and capabilities, the individuals involved in action learning are required to responsibly engage in the complex real-life problems. A result of such involvement is the development of effective multi-perspective solutions for the complex problems and reaching to intended change. Such change, according to Zuber-Skerritt (2002), affects both the issue or problem and the individuals acting upon the issue.

Zuber-Skerritt (2002) relates to action learning as learning from experience and a transformational change through critical reflection on knowledge and experience in group/team discussions, learning with others/from them, as well as inventions. Critical to the process of action learning is the way a group of learners address complex issues in the context of an organisation. Zuber-Skerritt (2002) further specifies that the solutions developed in action learning may need the organisation to change. Such solutions are often challenged by senior managers. The distinguishing feature of action learning is that learners accept and own both the issues and the solutions they devise. Even when senior managers provide expert solutions, learners tend to proceed with their own solutions. In this way, the learners themselves develop as the experts on recognising the issues at hand and on the way to solve them.

The form of learning that occurs in action learning is in fact based on reinterpretation of existing knowledge in individuals' minds as well as their re-calling of past experiences. This is a social process among two or more individual learners who, because of their differences in knowledge and insights, make each other test and scrutinise many ideas, including the misconceived ones. In line with that, action learning has powerful embedded mechanisms that make learners aware of their own value systems. Such mechanisms demand that dealing with the complexities of the issue at hand does have some risk of failure and that learners help each other based on what they genuinely believe. The value judgement in the action learning therefore empowers individuals to undeceive themselves (Revans, 1981).

When the circumstances are complex and no one knows the answer to a shared problem/question, action learning brings about advantages. The complexity of the issues might be that those charged with decision making are uncertain and do not know whether they can succeed in resolving the problem. It can also be that the solutions are not cheap, simple or quick (Zuber-Skerritt, 2002).

Further, similar to the argument on the importance of routines and activities in terms of the localities where learners' skills and capabilities are developed, as well as the importance of facilitating the embedded collaborative learning, action learning relates to tasks as the means of learning in order to develop learners in the organisation. Revans (1998) states that:

> *"No learning without action and no action without learning" (p.83).*

According Zuber-Skeritt (2002), the common understanding of the nature of action learning is based on learning by doing, reflection on practice, experiential learning, workplace learning and learning to learn. In effect, the terms "action learning" and "experiential learning" have been used interchangeably. Experiential learning is a cyclical process best modelled by Kolb (1984) and strives to raise our perception from an unconscious state of understanding to the conscious position. This process of becoming aware is carried out through experience of questioning the underlying assumptions, i.e. value judgements (Revans, 1981). Kolb's (1984) model is illustrated in Figure 8.

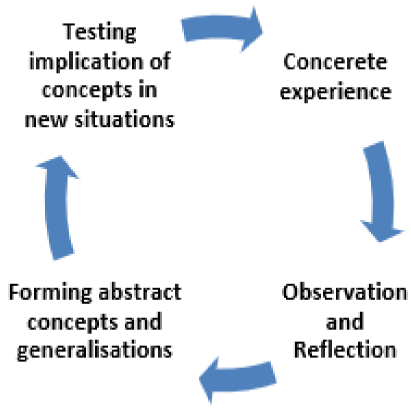


Figure 8: Kolb's (1984) Experiential Learning Cycle

The optimal balance between action and learning is important in action learning. Action is not the end goal in action learning but the means to achieve learning (Rooke et al., 2007), and it is through the reflection that profound development can happen (Pedler et al., 2005). People in such a balanced process can develop skills and capabilities from their experience and realise new ways of better learning and doing (O'Neil and Marsick, 2007). In the case of imbalance between action and learning, reflective practice can be used as a strategy for future action (Raelin, 2001, 2008). Reflective practice can turn tacit knowledge into explicit knowledge (Raelin, 2001). This is a process in which individuals step back from experience in order to comprehend what it means with a vision to plan for future actions (Coghlan and Brannick, 2014). Social dialogue, problem examination and systems thinking (Smith, 2001), individual and team feedback (Conger and Toegel, 2003) and action learning discussions (Maltbia and Marsick, 2008) are examples of reflective practice.

Kolb and Kolb (2009) offer six principles for experiential learning: (1) learning is a process not an outcome; (2) re-learning happens in all learning; (3) coordination and conflict resolution are required in the learning process among opposing dialectical forms of adaptation to the environment; (4) learning is the process of adaptation in a holistic way; (5) learning emerges as a result of synergetic operations among people and the environment; and (6) learning is a process through which knowledge is created.

Upon reflection, it appears that action and experiential learning have powerful embedded mechanisms to facilitate learners in taking on the responsibility of their own learning as well as collaboratively developing skills and capabilities in order to help themselves in the processes of acting and learning, even beyond their comfortable zones. In effect then, the skills and dynamic capabilities that emerge from action/experiential learning (in tasks, routines and developmental activities) are seen as having an influence on organisational performance (Zahra et al., 2006; Teece et al., 1997).

Although action and experiential learning were originally pioneered in work organisations and not in the educational systems (Zuber-Skeritt, 2002), experiential learning can be deployed through institutional schemes of development such as student development, curriculum design, and faculty progress in HEIs (Kolb and Kolb, 2005).

In the context of HEIs and the education domain, whilst the currently-emergent education paradigm strives to define universities as institutions that exist to create learning rather than institutions that exist to give instructions (Barr and Tagg, 1995), in practice there is still a long way to go (Catmull and Wallace, 2014). In this line, Breunig (2017) reveals that current literature has a consistent body of studies in relation to problem-based learning and transformational education. These approaches empower both the learners and the teachers in carrying out research, combining practice and theory, as well as in applying skills and capabilities. They are known as learner-orientated, instructional-centred and curricular-centred approaches (Walker et al., 2015). Yet, learner-directed knowledge sharing and collaborative learning (i.e. the subjective claim of experiential learning) have not been explored and only too few empirical studies exist in this arena (e.g. Ossa Parra et al., 2015).

Experiential learning as a kind of active experimentation relates to the intended purpose that guides the learning process (Breunig, 2017). According to Dewey (1938), there are two different types of experience. Primary experience is an incidental interaction and engagement. The secondary experience endures the reflective examination process that mixes past experiences in line with thoughts for future experience. Dewey (1938) specifies this as an experiential continuum in a purposeful way. Buck and Akerson (2016) and Estes (2004) call for studies that use consistent values (both those which are perceived and those in practice) within education scenarios. They state that those who teach and practise the experiential and student-centred learning are themselves very often teacher-centred following hierarchal and instructional approaches. Considering such values in connection to devising the purpose of the system, Roberts (2012) argues that much of the experimental learning in the current education domain and on school campuses fails to accommodate the warning made by Dewey (1938) of reductionist approaches towards experience just for the sake of experience. Roberts (2012) therefore calls for greater purpose in experiential learning in the education domain.

Since experience and experiential learning is a feature of communities of practice, and based on what was discussed in Section 2.4.2, HEIs in general, and classrooms in particular, are considered as knowledge networks or, in other words, as communities of learners. These communities of learners have the capacity to become purposeful communities of practice through implementation of routines and activities that revolve around students' experiential learning. However, the literature in the education domain is widely focused on communities of practice for teachers and formal learning instructors. According to Wenger (2011), the first application of community of practice began in teacher training. It made a provision for the lone administrators to have access to colleagues. The trend still has an interest in peer-to-peer activities for professional development. He emphasises that, in the education domain, communities of practice relate to a deep transformation. There are three educational dimensions that are influenced by communities of practice: (1) the internal perspective relates to the question of how we can arrange instructive experiences around the learning that happens in the schools and faculties, through participation/involvement in the communities of subject matter; (2) the external perspective focuses on how to link the students' experience to actual practice, which happens outside school, through peripheral types of participation; (3) the life-long perspective pays much attention to how to set up communities of practice for students' lifetime learning demands in the areas in which they have interests after they finish their school's programmes (Wenger, 2011).

In accordance with the context of action research in this thesis, the researcher aims to develop an open and collaborative space community in order for students to take ownership of their own learning through experiential learning and practising of the subject matter of mathematics and statistics. In fact, the courses or modules that have elements of tacit knowledge, such as modules that contain mathematical and analytical concepts, can greatly benefit from the community of practice approach. The community style for practising maths based on the viable system model and social network, in contrast with the current trends of the literature (which focus mainly on cognitive, instructional, behavioural and top-down perspectives) relates to social aspects of the facilitated process of collaborative learning, and participation through social interactions. This community style is therefore predicted to bring about change in the system, to enhance the skills development and to improve the performance.

In addition, the progress from single-loop learning to double-loop learning within the scope of action and experiential learning reminds us of Dewey (1938), who is cautioning us not to take the reductionist approach to experience. With due consideration and in line with the secondary experience that he introduces, it can be argued that value judgement in experiential learning is a means for understanding, questioning, critiquing and, if required, changing the purpose of the system, which illuminates the double-loop learning. In addition, the very continuous act of 'practice' in the cycles of experiential learning is a way to extend the continuum of purposeful experience, which in turn facilitates the gradual emergence of expert learners. This purposeful practice and experience is particularly very important when we are dealing with situations that involve a combination of tacit and explicit knowledge. The tacit element of the knowledge is very difficult to share. Learning by doing and several practice activities and routines that are available in the cycles of experiential learning are very effective mechanisms that can assist in this regard.

With the application of the viable system model as a purpose-orientated, bottom-up and facilitative approach which provides friendly and non-hierarchal space/environment, this study strives to fill the urgent gaps mentioned above. The collaborations in experiential learning illustrate the progress from single-loop to double-loop learning within the embedded processes of knowledge sharing, through social interactions, conscious reflection, value judgements and further probing the conceptualisations. These contexts, as well as the roles that collaborative knowledge sharing and the experiential learning facilitator can play, along with conflict resolution processes and the demand for adaptation to the environment, as discussed in the previous section, reveal the relevance of using viability theory and second-order cybernetics. The suitability of VSM has also been justified methodologically in Section 2.3.3.

Finally, based on the above, it is evident that the collaborations, the progress from single-loop to double-loop learning and its underpinning mechanism, i.e. social interactions, conscious reflection and value judgment, create an arena of complex interdependency and interconnectivity. No one is isolated in such a sphere. The evolution of individuals throughout the process relies on mutual contribution and experiencing and learning (Bateson, 2016). Such a dynamic interactive learning context contributes to the development of redundancy of potential command (Espinosa and Walker, 2017). This is because the potential to perform in an effective way is convened by sufficient concentration of knowledge and information (e.g. where collaborative knowledge sharing and collective learning and experiencing occur). The redundancy of potential command also reveals that "power resides where information resides" (Adams, 2011, p.151). The redundancy of potential command therefore advocates the development of a shared way of leadership for the system. In addition, according to Probst and Ulrich (1984), given that social systems are self-organising and that self-organising systems follow the principle of redundancy of potential command, every individual can be considered as a potential leader. This brings to light the co-responsibility of every individual and how leaders can emerge.

In this arena, the issue of what can be the underlying mechanisms or processes that contribute to the development of leaders as well as development of leadership, is unsettled. The next section offers a literature review that revolves around the topic of leadership development.

2.4.3. Literature Review: Leadership Development

The discussions in this section serve to briefly provide the theories that can explain the leadership development and emergence of leaders.

2.4.3.1. Leadership Development: Definition and Concept

Leadership development has been mainly defined in the literature at the individual level and looks rather like leader development. There has been less focus and less frequent reports on leadership development at group/team level or whole organisation level (Day and Dragoni, 2015; Day, 2000).

Leadership development, as Van Veslor et al. (2010) suggest, is the amplification of collectives' capacity to self-organise, to find directions, to generate alignment, and to create commitment. Collectives can be a group, a team or an organisation of individuals. In addition, DeRue and Myres (2014) indicate that leadership development is "a process of preparing individuals and collective to effectively engage in leading-following interactions" (p.835).

Both of these definitions can be used for the three levels of individual, team and organisation. Day (2000) reflects on leader development and leadership development and provides the distinctions between the two concepts by referring to four dimensions, namely capital type, leadership model, competency base and skills. Table 10 shows these differences.

	Development Scale	
Dimensions	**Leader**	**Leadership**
Capital Type	Human	Social
Leadership Model	Individual • Personal Power • Knowledge • Trustworthiness	Relational • Commitments • Mutual Respect • Trust
Competency Base	Intrapersonal	Interpersonal
Skills	• Self-awareness • Emotional awareness • Self confidence • Accurate self-image • Self-regulation • Self-control • Trustworthiness • Personal responsibility • Self-motivation • Initiative • Commitment • Optimism	• Social Awareness • Empathy • Service orientation • Political awareness • Social Skills • Building bonds • Team orientation • Change catalyst • Conflict management

Table 10: Disticntions between Leader and Leadership (Day, 2000)

2.4.3.2. Leadership development: Processes at Individual Level

At the individual level, leader development is considered as a journey for an individual with predisposed/inherent skills for leading (Arvey et al., 2007) based on intelligence/knowledge and personality traits (Judge et al., 2004). According to Day et al. (2009), the development of leadership skills and knowledge over time and through experience might have originated in earlier transformations in the person's self-views. However, they discuss how, in determining whether early signs of personal transformation lead to an actualised change towards development of a leader, the ability of individuals to practise mindfully/consciously the various ways of life and interacting/communicating with others and the availability and access to support, are important.

In addition, the influential factors in leadership development are the development of dynamic skills (Fischer, 2008) as well as the development of structures/processes required for one's understanding and making sense of complex phenomena (McCauley et al., 2006).

The structures and processes for meaning making in complex tasks (McCauley et al., 2006) suggest that individuals evolve from being exposed to particular assumptions, values and beliefs of other people to judging such beliefs in an objective way and through complex levels of sense-making, resulting in differentiating between other people's beliefs and self-owned beliefs. This then evolves further to possibly constructing their own complex assumptions and values. It is evident that development in this perspective is considered as a continual process of knowingly judging/critiquing earlier unknowingly-believed assumptions to eventually creating an individual's own identity. This is what is referred to as the process of self-transforming consciousness (Day and Dragoni, 2015).

Fischer's (2008) dynamic skills view asserts that there is no separation between cognition and emotion processes. Instead, they are interwoven indivisibly together to create actions and to provoke/inspire thoughts. According to Day and Dragoni (2015), through dynamic skills, individuals would function more holistically compared to traditional competencies and self-view perspectives. Hence, depending on the variability of cognition and the stability of the emotions of each individual, leader development programmes can be adjusted in terms of level of provision and forms of resources. Such levels of cognitive variability and degree of emotional stability, along with hierarchy of skills distribution and deployment, justify what is called a web of skills development. The web of skills development is more dynamic and accepts that individuals are able to function at various levels of a specified skill at any time. This perspective offers a more precise explanation as to the complexity of leadership development, since leadership itself as a phenomenon is rather complex and nonlinear.

Further, the fact that leadership can be developed has been suggested based on empirical evidence (Arvey et al., 2007; Van Velsor et al., 2010). While individuals can develop their skills over time and through coaching (Ladegard and Gjerde, 2014), mentoring (Lester et al., 2011) or in skills training (Dvir et al., 2002), which are offered in organisations, from the experience perspective, Dragoni et al. (2009) suggest three measures for predicting leadership development: (1) having access to developmental activities; (2) having experience in challenging developmental tasks; and (3) having strong learning goal-orientation. The authors call for studies that consider leadership development processes and underlying mechanisms for turning developmental experiences into leadership skills and performance. Similarly, Day and Dragoni (2015) encourage future empirical studies on the developmental perspectives through designing methodologies which generate insights into the dynamic process of leadership development.

2.4.3.3. Leadership Development: Processes at Collectives Level

At the team and organisational levels of leadership, the overall teams' capabilities, according to Hackman et al. (1978), can be explained partially as a function of the capabilities of individual members of the team. Day et al. (2004) also suggest that summation of individuals' capabilities for leadership may partially derive the team's leadership capacity. However, further research is needed to shed light on the underlying processes that create such a combination of capabilities. Nonetheless, according to Kalisch et al. (2009), some initial indicators at the team level may signal the potential for further development of collectives' leadership. These include: (1) a shared understanding/mind-set about the group's direction; (2) the group's engagements/interactions in some kind of collaborative learning; (3) knowing each other's skills in the group; and (4) the presence of psychological safety among group members. In addition, team exposures to remedial actions or certain collective experiences can facilitate the leadership development at the team level (Kalisch et al., 2009). This can be through group training that improves teamwork (Marks et al., 2000), or training that enhances group coordination (Espinosa et al., 2004), as well as working together in a team for a prolonged span of time (Reagans et al., 2005) and having a learning-orientation facilitator/leader in the group/team (Kozlowski et al., 1996). However, Day and Dragoni (2015) call for further research to investigate whether such actions or collective experiences are effective in forming the collectives' leadership capacities.

According to DeRue (2011), the collective leadership capacity is represented through a shared/distributed leadership structure. This type of structure emerges as a sufficiently stable feature of the team and permits the team to be adaptive in responding to a variety of demands in the environment. Ancona et al. (2015) assert that the best adaptation to the demands that come from the external environment and the internal dynamic occurs in an organisation where a more vivid direction emerges, commitment is improved via interactions/engagements among those who demonstrate leadership, whether formal or informal, and when processes become more aligned. It is evident that within the distributed leadership perspective, what mainly facilitates the timely development of collective leadership capabilities is the intensive relational interactions among individuals in an organisation (Ancona et al., 2015; Klein et al., 2006), since leadership is a process of social influence. Further, McKay (2016) perceives leadership as a transitory state that does not depend on individual leaders. He refers to leadership as "an autopoietic social system […] that alternates its existence with the organisation system, with the transition between them taking place at junctures triggered by grand uncertainty presented in the form of the 'wicked problem'" (p.2). Sice et al. (2013) also relate to the autopoiesis perspective and suggest that for developing leadership capability "what is required is to foster an environment where awareness is actively developed, fragmentation of experience is avoided and language is used to promote creativity" (p.1).

Having studied the aspects of leader and leadership development in this section, the last part of the theoretical review and conceptual analysis for this chapter is now completed. The following section provides a brief description of where the students' learning and skill development occur in an action framework.

2.4.4. Knowledge Sharing for Learning – Action Framework

The action framework of the present research is provided in this section. Figure 9 illustrates the position of the intervention for collaborative maths knowledge sharing, experiential learning, and practice, as well as skills development in this research.

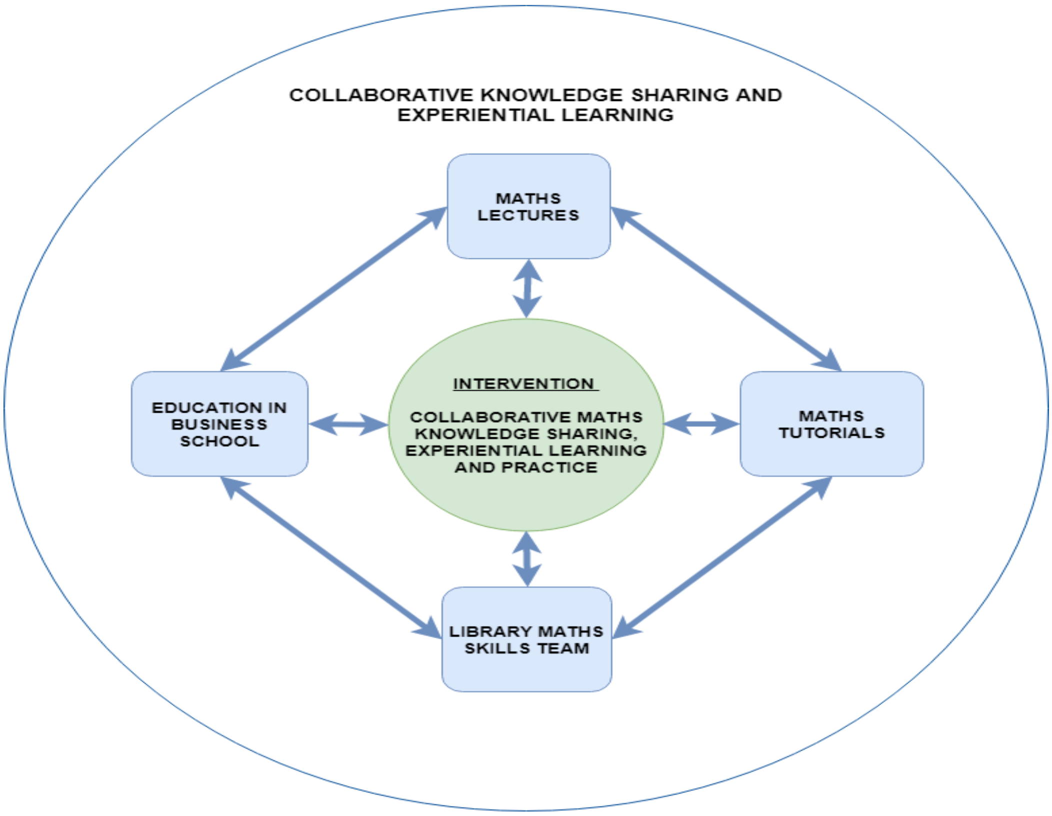


Figure 9: The Knowledge Sharing Action Framework of the Research

As is evident, there are arrangements for formal education at the research site of this study. There are 'maths lectures' in place as part of the APS module, where a lecturer teaches the maths concepts. There are also 'maths tutorials' where tutors attempt to solve certain maths questions and explain them to the students. In addition, within the university there is a 'library maths skills team', which can help students upon request per the particular maths topic that each student struggles to understand. The 'education in business school' refers to the arrangement of the learning environment to become skilful in maths and statistics and to perform well in the APS module. The intervention for 'collaborative maths knowledge sharing, experiential learning, and practice' is in the middle of the framework and is linked with other arrangements. The intervention is a solution that will be designed as a classroom of students containing a community of learners inspired by the viable system model. Figure 10 illustrates the schematic of how the solution will be structured.

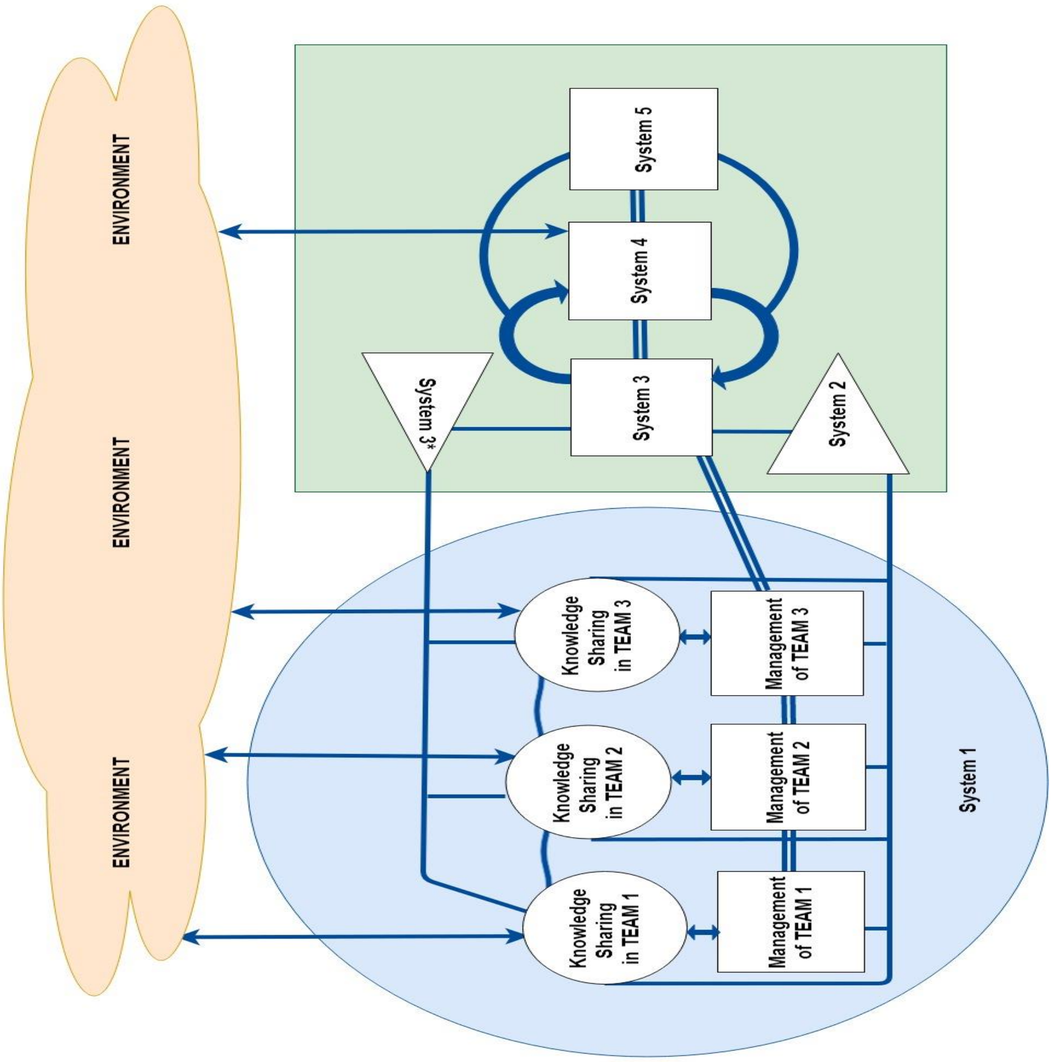


Figure 10: Schematic of Solution in terms of VSM in a Classroom as a Knowledge Network

The collaborations in knowledge sharing and practice will be carried out in teams. Teams in the classroom will also be able to share knowledge with each other. Students can act in each capacity in system 1, system 2, system 3, system 4 or system 5. What is important for them is to become conscious and aware of their actions and decisions and to appreciate/comprehend the capacity based on which they act or decide. The recognition of whether or not they are able to participate in the knowledge sharing and practicing activities in a particular system (e.g. system 1, system 2, … system 5) which requires specific capacities, would depend on their initial skills. By developing and enhancing their skills, as well as observing other students who act in other capacitates, they can also develop skills in other capacities through gradual participation in the work and discussions in the respective capacities of system 1, system 2, system 3, system 4 or system 5. Full explanations of each of the components will be provided in Chapter 4.

Having discussed the literature review and action framework, the following section provides the research questions for this thesis.

2.4.5. Research Questions

Research Question 1: How can middle-ranked UK business schools strengthen their ability to understand and manage the complexities involved in knowledge sharing processes (for student learning) using a systemic multi-methodology?

Research Question 2: How can middle-ranked UK business schools enhance learners' skills development and performance improvement using a systemic multi-methodology?

Research Question 3: How can a systemic multi-methodology facilitate the design and development of effective knowledge sharing structures and processes?

Research Question 4: How can a systemic multi-methodology assist in uncovering and eliminating the structural fragmentations in a knowledge sharing network?

Research Question 5: How can social network ties shape a team's knowledge sharing skills and capabilities in a system?

Research Question 6: How can VSM theory support network cohesion in a knowledge sharing network?

The researcher intends to design a realistic and practical approach for complexity management in a knowledge sharing project. To deal with such complexities, the intended research methodology should aim to provide a foundation for a learning process which assists people in improving and advancing their skills and capabilities in order to face current and future complexities.

Chapter 3: Research Methodology

3.0. Introduction

This chapter presents the orientation, paradigm, philosophy, model and methods of research for this thesis. It also embarks on designing a methodology in order to support the intended process of action research for this study. Although some authors differentiate a research methodology from a methodology of actions, the two are interlinked in the sense that a research methodology clarifies the foundations of research and a methodology of actions specifies the process of actions and operations (Espinosa, 2015; Midgley, 2015; Wilby, 2015 as cited in Sanchez, 2016).

In this research, the rationale and possibility for multi-methodological approaches emerged through reflection on the literature review chapter. A multi-methodology is referred to as a combination of systems methodologies (partly or in whole) designed to resolve a challenging problem situation. In effect, real-world problems are complex.

Operational researchers are increasingly employing multi-methodologies to cope with and manage such complexities (Henao and Franco, 2016). Philosophers have striven to address the need for, and the viability of, the methodological and theoretical pluralism (e.g. Roth, 1987). Sometimes researchers employ methodologies that were originally designed for other purposes. Flood and Romm (1995) term them oblique methodologies.

Midgely (1997), however, argues that it is better to see these oblique interpretations of the case studies as a creative design of methods. In this vein, the combination of different methods and approaches is frequently referred to as a multi-methodology (Mingers and White, 2010; Pollack, 2009; Flood and Romm, 1996; Mingers and Brocklesby, 1997; Jackson, 1997).

Whilst there are challenges involved in the mix and match of the methodologies (Tashakkori and Teddlie, 2010), it does, however, offer significant advantages. These advantages are: (1) the utility and value in applications; (2) more comprehensive ways of addressing the problems; and (3) generating more compelling conclusions (Ivankova and Kawamura, 2010, p.582).

In this chapter, the researcher first introduces the methodological orientation of the present thesis in terms of philosophical positions, and research paradigms. The chapter then provides the theoretical arguments and discussions regarding the design and development of the methodological framework of the research. The chapter concludes with assessment of the designed methodology (see Chart 2).

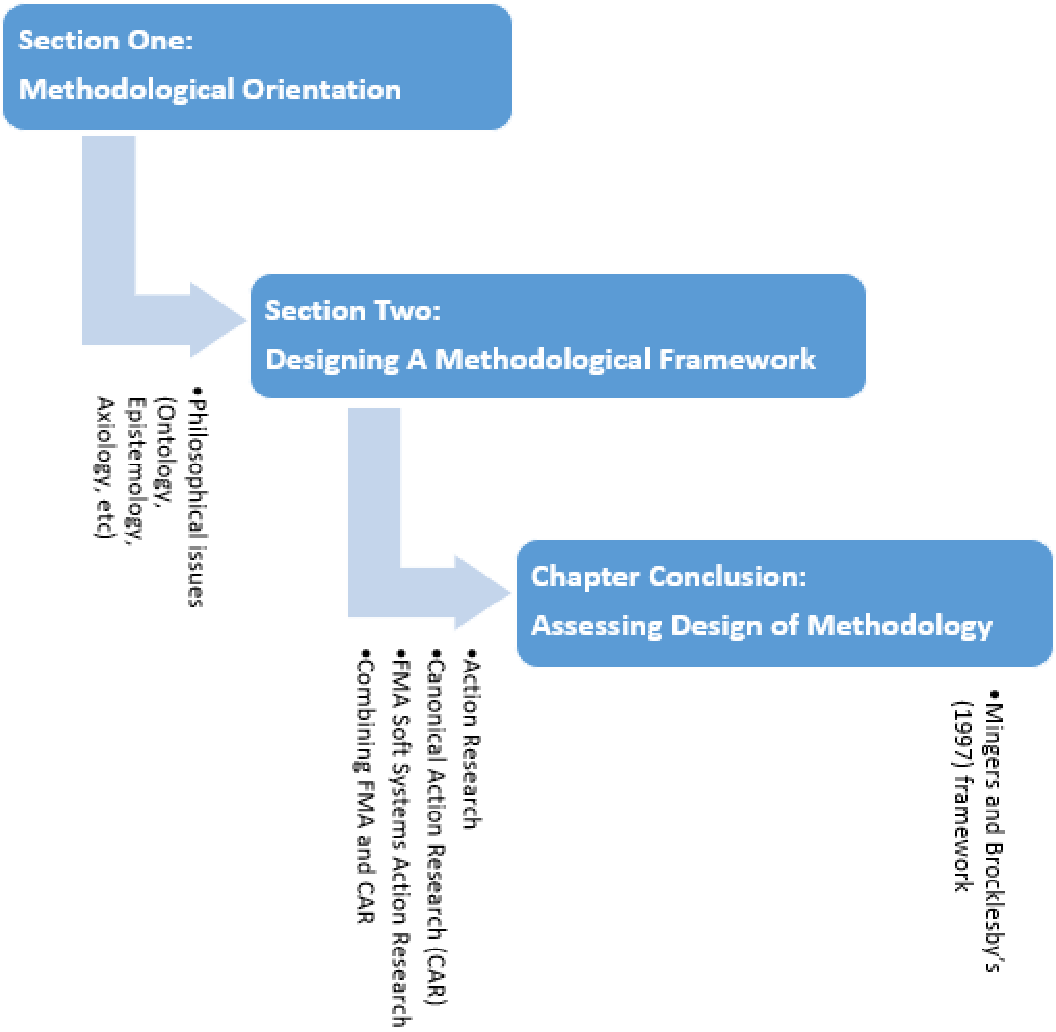


Chart 2: Sections of Methodology Chapter

3.1. Section 1: Methodological Orientations in Research

There exist two main perspectives for methodological considerations in social sciences, namely the "reductive methodological frame of reference" and the "complexity thinking methodological frame of reference". The reductive methodological frame originates from Descarets's rules of reduction. The researcher is to think solely about isolating the phenomena from each other and from the surrounding environment. According to Montouri (2008), the researcher in this perspective is supposed to reduce, simplify, and clarify the phenomenon in terms of an "either/or" logic, which is borrowed from Aristotle. There is no consideration for any form of paradox or possible ambiguity, neither for interactions and integration. This perspective is also in accordance with Newton's scientific method, which is so-called reductionism, i.e. breaking the system down into its simplest elements and attempting to understand them. The prevailing mind-set here revolves around perceiving the world as a set of components separable from and undependable on each other, assuming a linear cause and effect link between the components. Such linkages are also assumed to be reversible. This argument leads us to accept that we have an eventually knowable and predictable structure and behaviour.

In contrast, under the complexity frame of reference, the variations, ambiguity and uncertainty are recognised and systems are understood in terms of diversity in interactions, relationships, structures, and emergent properties. In this frame, many systems' components are dynamically interacting (Wimsatt, 1994) in a nonlinear way. It is rather up to the nature of interactions to determine the behaviour of the system, than the features of the system's components. Therefore, the relationships among components play a pivotal role (Rogers et al., 2013). It is also important to note that the outcomes of interactions are co-determined by temporal and spatial contexts. Hence, seemingly similar systems with a dissimilar background/history or those in differing situations occurring in different places should be considered different. In addition, since there exist varied feedback loops (direct and indirect), it is not possible to conclude on the relationship between the scale of the outcomes and the scale of the causes. This issue results in unpredictability of the system's behaviour. Further, according to Cilliers (2000), it is not realistic for us to claim an ultimate understanding of the complex systems in space or time. Hence, scientific objectivity is principally a myth. Moreover, according to Rittel and Webber (1973), in the complexity perspective, most problems are wicked. When it comes to framing a wicked issue, there exist various justifiable methods. Research studies under this frame of reference therefore tend to use an inductive approach as a method of thought in order to determine possibilities.

In this thesis, and as discussed in Chapter 2, the researcher argues that the process of knowledge sharing should be investigated through the complexity frame of reference. This argument is underpinned by two critical ideas. First, knowledge is a complex phenomenon. It is specific to each individual's belief, past experience and ways of perceiving and interpreting the phenomena in the world. Second, the act of sharing only makes sense in a network of n-social agents (n>1). When n increases, the level and scale of interactions increase exponentially. The interactions by themselves are of different types and varieties. Therefore, it is pertinent to study the process of knowledge sharing from a complexity perspective.

3.1.1. Complexity Research Paradigms and Philosophical Issues

A paradigm, as Guba and Lincoln (1994) refer to, is a set of underlying beliefs, assumptions and metaphysics that illustrate a worldview. This worldview is underpinned by ontological, epistemological and methodological assumptions. Neuman (2003) suggests that a paradigm is a system of thinking and an essential orientation towards the research and the theory. Gummesson (2000) considers a paradigm as:

> *"people's value judgements, norms, standards, frames of reference, perspectives, ideologies, myths, theories, and approved procedures that govern their thinking and action" (p.18).*

All research studies are established as well as carried out within a philosophical paradigm. Every paradigm relates to specific philosophical concerns. It focuses on the debates surrounding ontology, epistemology, axiology, methodology and methods and interlinks among them. Such analysis then clarifies the most appropriate research strategy for a specific research study (Lehaney and Clarke, 1995).

In social science, the philosophical debates are rooted in the two opposing viewpoints of positivism and interpretivism, resembling the objectivity and subjectivity of the research, respectively. According to Gill and Johnson (2010), the criticism of the positivistic approach and its propensity to use a reductionist lens for studying human behaviour, has given rise to interpretivist approaches. The objectivity and subjectivity in fact resemble a continuum based on which different paradigms and philosophies have been developed. Mukhuty (2013) gathers and illustrates the main paradigms, philosophical standpoints, and their important features (see Appendix 1).

According to Neuman (2003), the most effective approach with which to conduct a research project is established around the nature of the case as well as distinctive philosophical assumptions, principles, and viewpoints that emerge from its context. In the context of this thesis, which relates to the process of knowledge sharing and learning in a community of learners, the researcher aims to change the status quo, develop learners' skills and competences, and improve their performance. Hence, in line with the complexity frame of reference for this research, and considering the philosophical objective-subjective matters revealed in Appendix 1, the researcher will follow a pragmatist philosophy. In pragmatism, practical results and consequences of actions have significant roles in determining the meaning and truth of social reality. The argument here is that the meaning of a concept or idea is connected to, and can be equated to, the conceivable practical results of the actions. In fact, there is an assertion that if a theory justifies itself more successfully in predicting and dealing with the complexities of the problem than other theories, it can be regarded as nearer/closer to the truth. Within the pragmatist philosophy, it is now important to discuss and clarify the ontological, epistemological, methodological and axiological standpoints of this research.

3.1.1.1. Ontological Stance

Ontology represents the nature of reality or existence of things. According to Burrell and Morgan (2017, 2009), the objective perspective, or the positivist view, considers social reality as something that exists tangibly out there in the world. It does not matter whether the individuals discover and recognise the existence of such reality and its structures. The reality exists in an unchangeable form and concrete structures. This is referred to as realist ontology. On the other hand, in the subjective perspective (anti-positivist view), it is the very human understanding and the interpretation that manifest the social reality. In fact, shared meaning among individuals and their understanding discover or provide the social reality. This type of ontology is therefore subjective to human cognition and is called nominalist, which fiercely opposes the realist ontology.

In this vein, pragmatist philosophy benefits from an ontological view, in which the nature of social reality or being has the potential to be mutable. In fact, a belief can pass from being the reality to being unreal/untrue and back to reality again. This assumption refers to the truth as being relative to the concept and the way the concept is recognised (i.e. the conceptual scheme). The researcher therefore accepts that the social reality is not always ready-made but is something that both the social agents and the social reality can mutually make real (Putnam, 1987; James, 1975). In pragmatism, the truth is considered as the social agent's transformation and revolution of experience. However, this must not be confused with reality becoming freely constructible or imaginable as the social agent pleases (Schiller, 1907). This relational property for the nature of reality or knowledge provides a relativist ontological standpoint for the present research.

3.1.1.2. Epistemological Stance

Epistemology is rooted in 'episteme', a Greek word which means knowledge. Epistemology is therefore the study of knowledge as a theory. It thus examines the way in which knowledge and its justification are being acquired (Jary and Jary, 2000). In other words, the questions that we ask or we could potentially ask are under the influence of epistemology. The beliefs and perceptions, as well as the rightness of and the truth about our current knowledge (what we already know), are also assessed through epistemology.

With the positivism-anti-positivism continuum of epistemological assumptions, from one side, getting the true knowledge refers to the objective viewpoints and ensures justification of the claims through checking whether the hypothesis can be possibly falsified or through repeating the same scenario in controlled conditions. From the other side, the subjective anti-positivism takes a variety of forms, i.e. interpretivism, constructionist, feminist, pragmatism, etc., as provided in Appendix 1. According to Burrell and Morgan (2009), understanding the subjective viewpoints of those who are actively involved, and their interrelations in the case under investigation, can bring to light the true knowledge, compared to an external observation. Hence, closely linked with ontology, there are many and varied sources for creation, accumulation and continual development of social reality/ knowledge which are revealed in epistemology. These are referred to as epistemic sources of knowledge.

In this arena, central to pragmatism is "experience", because of its real-time relevance and application as well as its future prospects for the philosophy (Pappas, 2014, p.1). Pragmatists such as Dewey (1938) state that "experience for philosophy is method, not distinctive subject-matter. It also reveals the sort of method that philosophy needs". Pragmatists consider experience as the best vehicle for obtaining knowledge. Pappas (2014) reveals that experience serves three functions. First, it critically uncovers the starting point for the investigations. Second, it prevents pragmatists from making philosophical fallacy mistakes including starting with dualism, reductionism, neglect of context and equating the social reality to what is known. Third, it informs and reconstructs methodological prescriptions for edifying the traditional concepts of inquiry, ethics, self, etc. Experience, as a method, therefore, underpins a variety of activities and ideas that enable social agents to act or react in the environment. The argument here is that for issues such as a problem requiring solutions, the way the problem is selected, the data collection around the problem (which leads to problem structuring), and proposition/hypothesis development and experimentation are all steps of the experiential method. The social reality/truth then is the result of expected outcomes through such a method.

For the case of this thesis, which deals with dynamic interplay between tacit (experiential) and explicit knowledge within processes of learning, pragmatism fits well and the variety of experiential activities epistemologically provide a pluralistic stance for knowledge sources. However, it is important to note that whilst experiential learning is squarely suited to pragmatism, it is the scope of research that can be decisive in terms of what type of experiential learning would be included in the research. For instance, incorporating the experience of using maths learning software such as MyMathLab was not in the scope of this research. If it was in the scope, then Johnson and Liber's (2008) PLE approach could also have been used in the experiential learning. This is because the PLE approach uses VSM and claims that physical engagement with the technological learning tools plays a key role in empowering the learners to organise their own technological learning sphere. However, Johnson and Liber's (2008) PLE approach is yet to be tested for its effectiveness in learning, where there is a substantial level of maths knowledge (with tacit and explicit knowledge interplay) involved. If it was, this could have provided another source of capturing knowledge.

3.1.1.3. Axiological Stance

Axiology refers to the position and role of the researcher. It is important to clarify the researcher's role because such positions can affect the ontological and epistemological stances of the research. In the other words, the researcher's position can shape the nature of knowledge as well as the extent of the justification, rationality and validity of the study. According to Collis and Hussey (2013), the question of whether the researcher is independent or interacts with the phenomenon being investigated is important to epistemology. According to Remenyi et al. (1998), a researcher under a positivist epistemology is treated as being autonomous from the phenomenon in such a way that neither of them affects the other. On the other hand, anti-positivists believe that the researcher is part of the process of research. For example, in participatory action research, as well as in feminism, the research results may be influenced by the researcher's points of view and involvement. In fact, the researcher is managing the change and facilitating improvement for the phenomenon under investigation.

Axiology also relates to theory and the nature of value and discusses the issue of the researcher's value. This means clarifying and discussing whether the research is value-free or value-laden (May and Williams, 2002). In addition, axiology captures the answer to the question of what is essentially worthwhile (Heron and Reason, 1997). In this vein, positivists assume that research is not biased by the researcher's value, and hence it is value-free. On the contrary, the phenomenology perspective (anti-positivist) asserts that the researcher's value does affect all types of research. Therefore, research can proceed based on an explicit consideration and acceptance of the researcher's pertinent values and the understanding of such values as something that are not necessarily affecting the research adversely (May and Williams, 2002). In fact, in participatory action research, axiological questions about values are addressed in terms of human flourishing as a "process of social participation in which there is a mutually enabling balance, within and between people, of autonomy, co-operation and hierarchy" (Heron, 1996, p.11). Hence, "…values might be said to constitute the very subject matter of social sciences" (May and Williams, 2002, p.108). These values make it possible for "people to be involved in the making of decisions, in every social context, which affect their flourishing in any way" (Heron, 1996, p.11). It is clear, therefore, that pragmatism does not confer eternal values. The researcher and the participants in the research are creating the values. The creation or selection of values is underpinned by the consequences that such values might infer. Only if the value is considered beneficial in terms of solving the problem for the phenomenon under investigation will it be created/selected.

3.1.1.3.1. Pluralism in Researcher's Role

Under the pragmatist philosophy for this research, the researcher's role is considered pluralistic. Two key roles, namely (1) being a PhD student-researcher and (2) being a development facilitator, are perceived. In the position of a PhD student-researcher, the roles revolve around being VSM workshop facilitator, intervener, observer as well as a participant. From the position of a development facilitator, the roles of being a system analyst and a colleague/staff member, emerge in the process of operational/action research. Evidently, these roles are layered and complex. The combination of said roles, which necessitates an increased level of reflectivity for the continuous evaluation and learning, ensures an organisational cybernetic (cybernetics of cybernetics) study of the case. Internally also, it allows and facilitates the double-loop learning for the participants in their guided self-organised teams.

Being reflexive requires being regularly vigilant about one's own decisions, actions, behaviour, and their influence on the action/operational research and on the participants.

The values, priorities, desires and biases are manifested in the communication and dialogues as well as in behaviour. This also indicates that the practitioners, system analysts, development facilitators and researchers are part of the system and are involved and engaged in said system. This participatory scheme is crucial to the reflective behaviour of researchers on their own assumptions and biases. In this vein, research participants are also reflective on their own situation, values and assumptions (Sultana, 2007). In fact, reflection is analysis of how knowledge creation is shaped through the shifts in the context and relational dependency of researchers' social identity and their social positions (situatedness) among their subject participants (Brisolara, 2014).

3.1.1.3.2. Researcher's Values, Ethics and Biases

With reflection on pragmatist philosophy and the very importance of the researcher's values (Creswell, 2003), for this research, the researcher recognises herself as a maths teacher/learning practitioner with an unflinching and hands-on dedication to learning through experience and practice. She has completed a lot of work based on this lens before. She has regularly found herself noticing and judging those teaching-learning strategies that miss the value of second-order cybernetic, and double-loop learning, based on practice and experience for the tacit knowledge of maths. She assumes, therefore, that being merely an "unobtrusive or non-reactive" observer (Angrosino, 2005, p.732) or a "peripheral member" (Adler and Adler, 1987, p.39) could not fit with her practice values. From a systemic perspective, the change facilitator and the observer are coupled roles, important for effective assessment of the system (Midgely, 2000). Hence, the researcher as a conscious being can see that any interaction she makes contributes to the knowledge-generating system that she is part of.

Ethically also, the researcher used a standard guideline for the study and based on the roles she makes herself known as a PhD student-researcher or practitioner when meeting participants and obtaining their informed consents. This is, however, voluntary and subject to withdrawal upon participants' wishes.

3.1.1.4. Methodological Stance

Any research revolves around the framework, the overall approach and the process of that research. These are collectively known as methodology. Methodology includes all of the methods and procedures that are used in the operational conducts of the research. In addition, the validity and reliability of research instruments that assist the researcher in reaching the truth/social reality are also discussed in the methodology (Remenyi et al., 1998).

With reference to the objective-subjective continuum, when the focus is on objective perspective, methodology refers to “systematic protocol and techniques”. This relates to hypothesis testing through rigorous scientific benchmarks, and adapting quantitative methods such as surveys and tests (Burrell and Morgan, 2017, p.6). The subjective perspective, on the other hand, pays attention to the subject and develops a detailed and insightful account of its reality. The characteristics of the subjects, events and phenomena emerge gradually whilst the inquiry is proceeding (Burrell and Morgan, 2017; Remenyi et al., 1998). From the subjective perspective in a pragmatist philosophy, the focal concern is placed on how knowledge is created. In fact, a methodology based on pragmatism contemplates the active role of the facilitator, intervener or researcher in establishing the data, as discussed in the axiological stance. This data is then used to bring to light the social reality or knowledge and to provide the theories. In this vein, the researcher is practically participating in the system in focus to explore the impacts of different techniques and tactics based either on his/her own actions or through close observation of others. Such applications and evaluation of techniques, strategies and knowledge underpin the foundation of methodological pragmatism.

Further, central to methodological pragmatism is the use of various relevant methods. Hence, it adopts a pluralist view (Goles and Hirschheim, 2000). This means that methodological pragmatism establishes and uses the methods/combinations of methods, which provide a viable solution for the problems in the system in line with the purpose, context and situation of the research.

3.1.1.4.1. Methodological Pluralism

In systems thinking and the complexity perspective, Midgley (2000) argues that since a plurality of theories is acceptable, and that those theories can flow into methodology, it is legitimately possible to see a variety of methods or solutions combined. In addition, according to Burns (2007), systems thinking is a way of thinking about how social agents are relating to each other rather than a map of reality. He emphasises that the interactions and interconnections between social agents and the systems surrounding them, such as the organisation, underpin the transformative potentials of each situation and make each case unique. Lewis (2016) argues that the quality of this transformative power and the underlying interconnections can justify the application of a methodological pluralist approach. Burns (2016) uses an action research and combines participatory practices/processes/statistics, collective data analysis, systems mapping, story narratives, and interviewing within a systemic intervention. He refers to this combination as methodological plurality, characterised by embedded iterative methodological reflection. He then argues that high levels of rigour, robustness and impacts are achieved through methodological pluralism. It is, however, important to state that not all pluralistic solutions are pragmatic, but pragmatism is pluralistic in nature (Aikin and Talisse, 2016). For the systemic action research about knowledge sharing in this study, and under the pragmatist philosophy, the researcher intended to stay flexible, responding to the conditions, circumstances and the stakeholders involved. The action/operational research and the systemic solution here are built on iterative feedback and learning based on the developmental nature of the work.

3.1.1.4.2. Research Methods and Tools

Methods are the individual techniques adopted in the research as well as the usage of relevant tools in the conduct of the investigation and data collection. They can be generally classified as quantitative methods/tools (objective) and qualitative methods/tools (subjective). According to Jary and Jary (2000), quantitative methods/tools are associated with the positivist perspective. Quantitative empirical techniques and tools therefore measure and represent the data through numbers and ordinal figures. However, qualitative methods/tools relate to the interpretivist and phenomenological perspective. Along this line, the researcher uses a generally unstructured or semi-structured approach to extract the information. This happens, for instance, in case studies and observations. However, it is possible to show the data in a quantitative form after the analysis. Although quantitative and qualitative methods/tools are used based on the objective-subjective nature of the research, according to Darlington and Scott (2002), they can be mixed or triangulated to enhance the rigour, relevance and the strength of the research. This, however, depends on whether a mixture of methods is required in the research and the researcher would have to make a judgment to decide upon this. Here, for this research, the methods vary, ranging from traditional qualitative methods such as interviewing, to more change-orientated and developmental methods in organisation, such as guided self-organisation team activities. Since this thesis aims to design a systemic methodology for the present study, further details about the methods are discussed in Section 2.

3.1.1.4.3. Research Strategy

Social sciences adopt six key research strategies. They are: (1) experimenting; (2) conducting a case study; (3) surveying; (4) using grounded theory; (5) ethnography; and (6) action research. According to Cooper et al. (2006), the experimental research strategy entails a researcher's interference beyond the requisite measurement. In fact, the researcher usually interferes through manipulating some variables in a setting and then observing the effect of the manipulation on independent variables such as the participants or the subjects of the study. In doing so, the experimental research strategy uses a control group. Research based on experimenting can be simply repeated or replicated. However, the surrounding environment may affect the participants or subjects of the study. The generalisability of the research findings might also be restricted.

The case study strategy is used when the context plays a major role in the phenomenon. According to Yin (2003), case study is an effective empirical investigation of a current phenomenon in its living context to gain a deeper understanding of both. In particular, a case study research strategy is beneficial when there exist no clear boundaries between the phenomenon and its context. Although case study has a great potential to find answers about research questions, it is used mostly in exploratory/explanatory research and the results are difficult to generalise.

Surveying is a research strategy based on which information is obtained from a sample of participants through questionnaires or interviews. This is a method of data collection via communicating with a sample representing the population. The researcher in this strategy can embark on a quick administration of an inexpensive research study and easily code the data and analyse it. The analysis is then interpreted and a clear means is established for evaluating information about the population. However, people might refuse to answer, give false answers, or respond in a certain direction. Systemic error in the structure, form and wording of the question might also occur and affect the respondents (Zikmund et al., 2003).

Using grounded theory as a research strategy is “an inductive and more structured approach in which each subsequent depth interview is adjusted based on the cumulative findings from previous depth interviews with the purpose of developing general concepts or theories” (Malhora, 2010, p.189). Grounded theory is used to establish new theories through continuous interlinks between data collection processes and the data analysis. However, it is difficult to deal with the emerging large amount of data. In addition, generalisabilty of data is not easy to achieve.

Ethnography is another research strategy and studies human behaviour within its natural context. It entails in-depth interviews and observation of behaviour as well as observation of context and settings (Malhora, 2010). Ethnography underpins a different qualitative form of data collection through which the analyst/researcher seeks to understand the influence of the social as well as cultural context on people’s experience (Hair, 2007). Ethnography can be carried out via visual or audio recording. However, data collection, analysis and reporting the results are time-consuming processes.

Action research strategy, according to Tharenou et al. (2007), is “a design that simultaneously combines action to bring about change in a setting and research to increase and/or develop understanding on the part of the researcher, client group, etc. about that social system in order to develop knowledge” (p.89). Action research revolves around learning as well as change in social settings. It leads to a deeper and richer understanding of processes that were not understood before. Hence, it contributes to knowledge. Action research needs collaboration between the researcher and the participants, and hence it is time consuming. In addition, generalisation of findings is not easy.

3.1.1.4.3.1. The Choice of Research Strategy

This research chooses to adopt a case study action research strategy in order to understand the knowledge sharing and learning context and the phenomenon under investigation, as well as to design and develop a methodology to deal with knowledge sharing processes and structures. This strategy is more fitted to the pragmatist philosophy and methodological pluralism. The following discussions will provide more details on why case study is suitable for this research and how parts of this research have a strong relationship with the case study process of action research.

First of all, findings in a real-life problematic situation that needs transformation are important. According to Eisenhardt (1989), “case study is a research strategy which focuses on understanding the dynamics present within a single setting” (p.534). Eisenhardt (1989) suggests using case study investigation at the early stages of research, since it provides a fresh perspective on the context (p.546). This contributes to learning about the context in the area of application/concern. Having a deep and comprehensive understanding about the context in which the issues have arisen is also very important in making developmental decisions in order to transform the situation at later stages of the research. Importantly, in order to better capture the contextual processes in the organisation over time, a case study action research strategy can offer the longitudinal power that it has. Bengtsson and Larsson (2012) explain that complex organisational processes emerge and unfold over time and case studies have longitudinal power to reveal such patterns (p.15). The richness of interactions and involvement of people, teams, organisation and contexts over a time period can be studied better from an idiographic perspective as a case study rather than a nomothetic perspective on research (Bengtsson and Larsson, 2012, p.15). In addition, a case study is useful when the boundaries between parts of the system and the environment are not clear-cut. According to Yin (1994), a case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident" (p.13). Hence, in this study the implementation stage would benefit from undertaking a case study action research approach.

Using the case study strategy is particularly beneficial when the research explores the question 'How' and the question 'Why' about a specific research phenomenon (Yin, 1994). According to Welch et al. (2011), case study is a popular strategy for qualitative research. Case study is an established research strategy in not only management and organisational studies (Bengtsson and Larsson, 2012) but also in complexity management studies (Hammer et al., 2012; Vidgen and Wang, 2009; Mitleton-Kelly, 2011; Brooks, 2010), which is the case for this thesis. A case study design with a complexity approach provides a new way towards research in the organisations (Anderson et al., 2005). As in the case for this research, the case study action research will be facilitative in defining and understanding the system in focus, as well as taking a holistic perspective that considers the system as an integrated whole. These are all parts of the diagnosis and intervention planning and implementation stages of SOCR. Anderson et al. (2005) state that:

> *"Complexity theory is a useful companion to case study, because it simultaneously fosters an attitude of attention to emerging patterns, dynamism, and comprehensiveness while focusing attention on defined system properties" (p.681).*

In addition, understanding the complexities intrinsic to the system requires an observer with a second-order lens. Case studies provide deeper insights into processes of management, which are not possible through survey questionnaires or sources of secondary data (Beamish and Lupton (2009). This supports the choice of an organisational cybernetics perspective, as explained previously, and the importance placed on the role of observer in this research. It also facilitates the reflection/learning stage of the SCOR. This is because, according to Tsoukas and Hatch (2001), "complexity is not only a feature of the system we study; it is also a matter of the way in which we organize our thinking about those systems" (p.79). Casti (1986) also states that "complexity is in the eyes of the beholder" (p.149). Taking the research project as a complex system also, the researcher/observer benefits from evidence that supports the management of the research in terms of principles and associated criteria of canonical action research.

Further, in terms of efforts towards theory development, a case study strategy is especially good for the development of a new theory for a current and new phenomenon. Case studies also offer opportunities for noble narratives which increase our general academic understanding with reference to social phenomena (Bengtsson and Larsson, 2012; Flyvbjerg, 2006) through provision of illustrations of complex situations even in their own right. Case study action research, therefore, facilitates the development of the framework of ideas in terms of focal and instrumental theories.

Moreover, operationally speaking, a case study can also contribute to the understanding of the complexities of the learning context and collaborative knowledge sharing at the core of this research. This is because case study action research is helpful in studying the complex contextual situations and the provision of explanations that emerge from evaluation and reflection on the research.

Finally, case study is particularly helpful when combining varied methods of data collection for which evidence can be both qualitative and quantitative (Eisenhardt, 1989, p.534). The case study strategy also supports the methodological triangulations, which is sought after in this research on the way to methodological pluralism. Such mixing of methods or methodologies, as Mingers (2001) suggests, supports the move from original contribution to knowledge through research, towards implementing the findings of the studies. This is helpful in particular in linking the stages of the study in this research. It is important to note that the research design, according to Yin (1994), is a sequence that links the empirical data to the research questions from one side and to the conclusion from another side. However, Patton (2002) emphasises that “there are no perfect research designs. There are always trade-offs. Limited resources, limited time and limits on the human ability to grasp the complex nature of social reality necessitate trade-offs” (p.228). Based on his view, there is no law or rule, based on which the researcher can focus his/her study. For this study, the research design is specific to the issues/situations being addressed. It was developed based on the focal and instrumental theories that the researcher, as an involved observer, found justifiably relevant to the case. However, the research design was flexible/adaptable in the emergent situations of the complex organisational environment.

3.1.1.4.4. Research Approach

This research will follow an inductive approach to study the structure and process of knowledge sharing using the combinative lens of social network analysis and the viable system model. This will enable the researcher to bring to light new insights and understanding based on empirical observation, an outcome-orientated action research study, and an evaluation of the concepts (Collis and Hussey, 2013).

3.2. Section 2: Designing and Developing a Soft Canonical Operational Research (SCOR)

In light of the fact that the viable system model can be combined with the FMA soft systems account of action research in a transformational approach, to aid the facilitating and managing of change (Espinosa and Walker, 2013, 2017), I put forward a multi-methodology embedded in a framework which provides the practical structure and the details of combined methods. The purpose of this multi-methodological framework is to inform the breadth and depth of the action research process. The framework strikes to balance between the number of stages in the process and the level of details immersed within. Here in the present section I provide the arguments on the design and development of the multi-methodological framework.

3.2.1. Action Research (AR)

Action research has been defined as "a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this historical moment. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities" (Reason and Bradbury, 2001, p.1). Rooted in Lewin's (1947) work as well as Trist and Bamforth's (1951) research in Tavistock clinic, action research is the main methodology for change management and organisational development (Baskerville, 1999) and is a type of applied research. Action research's influential contribution to the literature is based on Susman and Evered (1978), who have formally offered a cyclical process model consisting of five stages: (a) problem diagnosis; (b) action design and planning; (c) implementing the actions; (4) evaluation; and (5) learning from the cycle. According to Thornhill et al. (2000), the action research strategy is built on cycles of reflections in a systemic way. The process initiates from a preliminary idea with the sketch and principles for operation/action research. The researcher then reflects on the experience and learning as well as on the theoretical and methodological pre-assumptions. The researcher is a part of the system within which research is carried out and so he/she is engaged from the very start (Checkland, 1999). This involvement happens in a collaborative way with the participants, towards a mutually agreed goal. In this way, the researcher acts as a facilitator, allowing the problems to emerge, and strives to guide the participants in resolving the issues (Wing et al., 2017). This is also consistent with the double-loop learning put forth by Argyris and Schon (1978), which persuades the researcher and the participants to reflect on actions in the system. The relationship between action and learning is vital in action research. In fact, a theory is developed based on understanding of this relation. As Baskerville (1999) states:

> *"Action should continue until the immediate problem situation is relieved. Actions that relieve an immediate problem setting are powerful evidence of the practical effectiveness of an underlying theory" (p.4).*

Hence, the aim of action research is to not only understand and elucidate the event under observation, but also to make changes and to improve the practice (Blaxter et al., 2001). According to Davison et al. (2004), action research focuses on solutions for resolving organisational issues and at the same time it contributes to the production of new knowledge. However, this type of research is criticised for lack of rigorous methodology (Cohen et al., 1982), not being different from consultation (Avison, 1993) and, according to Dickens and Watkins (1999), for lacking impartiality, creating either exploration with not much action or carrying out actions with not much research. In addition, action research can be expensive in terms of time and resources. There is also no easy way for the findings of action research to be generalised (Gray, 2013). However, Dick (2006) challenges this claim on generalisability and argues that if we assume so, we should not be able to learn from experience. This criticism has led to the development of different forms of action research. The process models, structure, objectives and researcher involvement are key criteria based on which different forms of action research have emerged and are classified. Drawing from information systems studies, Baskerville and Wood-Harper (1998) use these criteria and categorise 10 forms of action research. Table 11 illustrates these 10 forms and their characteristics. In addition to these types, Davison et al. (2004) report on two other forms of action research, namely reflective systems development and collaborative practice.

Klein and Myers (1999) argue that, with this wide range of variety in categories and the typology of characteristics, action research can hold in its nature the epistemological assumptions for any of positivism, interpretivism and critical theory. In this arena, however, action research resists the traditional reductionist view of the phenomenon in the world. It takes a holistic perspective and recognises the social realities as interconnected, dynamic and evolving (Greenwood and Levin, 1998, p.71). This view is in line and in agreement with taking a complexity perspective towards studying the phenomenon under investigation. It is important to note that in complexity and systems perspectives, positivist approaches towards action research are recognised as hard operation research (hard-OR). In contrast, interpretivist and critical perspectives are known as soft operation research (soft-OR) (Heyer, 2004).

	Process Model			Structure		Typical Involvement			Primary Goals				Example
Action Research Form/ Characteristic	Iterative	Reflective	Linear	Rigorous	Fluid	Collaborative	Facilitative	Experiment	Organisational Development	System Design	Scientific Knowledge	Training	
Canonical Action Research	•			•		•			×		×		Baskerville (1993)
Information Systems Prototyping	•			•		+	+			•			Kyng (1991)
Soft Systems	•				•		•		×	×			Checkland and Scholes (1990)
Action Science		•			•		•		×		×		Reponen (1992)
Participant Observation		•			•			•			•		Jepsen et al (1989)
Action Learning		•			•			•				•	Naur (1983)
Multi-view			•	•		+	+	+		•			Avison and Wood-Harper (1990)
ETHICS			•	•			•		×	×			Mumford (1983a)
Clinical Field Work			•				•		×		×		Hammer and Champy (1993)
Process Consultation			•	•				•	•				Coad and Yourdon (1991)

Key: • signifies a dominant characteristic, + (or) signifies characteristics that will dominate in different studies, × (and) signifies characteristics that may occur together in the same study.

Table 11: Types and Features of Action Research – Baskerville and Wood-Harper (1998, p.96)

Given the reflection on different types and features of action research in Table 11, the researcher chose to combine canonical action research and a soft systems account of action research in order to design the multi-methodology for the case study of this research, intervening in the problematic situation. These choices were made based on the approach, scope and topic of this research. For example, information system prototyping was not relevant because the context of this research relates to processes of experiential learning and learners' participations. In addition, multi-view, ethics, clinical field work and process consultation approaches were not relevant because they are more used in linear approaches. Further, Naur's action learning was not used because the soft systems approach could provide deeper action learning relevant to stages of the modelling approach. Hence, there was no need for another action learning approach. Moreover, the researcher did not use participants' observation and action science approaches because they both tend to go about generating scientific knowledge, whilst this research has an inductive approach which mainly aims at learning about the processes that are effective for knowledge sharing, learning and skills development. The choices made, i.e. canonical action research and the soft-system account of action research, are discussed in detail next, alongside an explanation of how this combination rectifies the shortcomings and criticisms of an action research; the methodological pluralism for this research is also provided.

3.2.2. Canonical Action Research (CAR)

Within all forms of action research, it appears that Canonical Action Research (CAR) is unique because of three characteristics. First, it is iterative, i.e. it is underpinned by the conduct of several cycles of activities within the cyclical operational research process, which is designed to deal with the challenges encountered in the organisation. Second, CAR is rigorous. This is because the iterations are carefully planned and activity cycles are watchfully carried out. Therefore, the researcher can establish a detailed and rich understanding of the problematic scenarios and deliberately facilitate the move towards the solution. In addition, problem diagnosis is a continuous process and through the researcher's engagement with such a process, the pre-planned activities are dynamically modified to be relevant to the current understanding and experience of the issues and challenges. Such dynamic relevance is hence an essential factor for a canonical action research to claim that it is rigorous. Third, canonical action research is in essence collaborative. The organisation and the researcher must work together within the particular conditions of the organisational problems and take culturally-appropriate process roles that suggest the dominance of neither the researcher nor the organisational client (Davison et al., 2004). Canonical action research requires investing in time in order to establish the essential relations with decision makers in the organisation and to operationalise all stages of the cycle. CAR therefore might take several weeks or even months and years to reach an end (Clark, 1972). In this vein, it is important to recognise that within the network of organisational actors and with emergent and evolving organisational conditions, full control over the actions is almost impossible, for any researcher or organisation (Davison and Vogel, 2000; Mumford, 2001). Hence, generally a completely definitive drawing of plans for action is impossible. In fact, the complexities involved in the CAR lead the researcher to be relevant and adaptable to a great deal of varieties of the conditions and circumstances, rather than to stick to a pre-determined machine style of techniques and actions (Descola, 1996). Nonetheless, to track the truthful evolution of the process, the intimate perspective on the problematic situation is developed. Constraints, peculiarities, and idiosyncrasies are taken into consideration. These, in turn, lead to producing the relevant findings for the organisation as well as enhancing boundaries of knowledge (Elden and Chisholm, 1993). CAR, similar to other types of research, combines the theory and practice. This is "through change and reflection in an immediate problematic situation within a mutually acceptable ethical framework" (Avison et al., 1999, p.94). The objective is to improve the practice as well as to contribute to theory and knowledge both within the boundaries of the project and beyond (Eden and Huxham, 1996).

3.2.2.1. Canonical Action Research Principles

CAR is structured around five principles, i.e. (1) creating agreement between the researcher and the client; (2) the use of a cyclical model for the process; (3) the use of theory; (4) making change/transformation by means of action; and (5) the principle of learning via reflection. The first principle relates to the development of a relation between the researcher and the decision makers in the organisation in order to facilitate their agreement on collaborating with each other (Foster, 1972). The second principle, i.e. the principle of the cyclical process model, refers to the necessity of commencing research and action based on a cyclical model. In particular, Susman and Evered's (1978) cyclical model for action process is adopted in CAR and comprises five stages: (a) diagnosis; (b) action design and planning; (c) implementation of the planned actions; (d) evaluation; and (e) reflection and identifying the lessons learned. This model is illustrated in Figure 11.

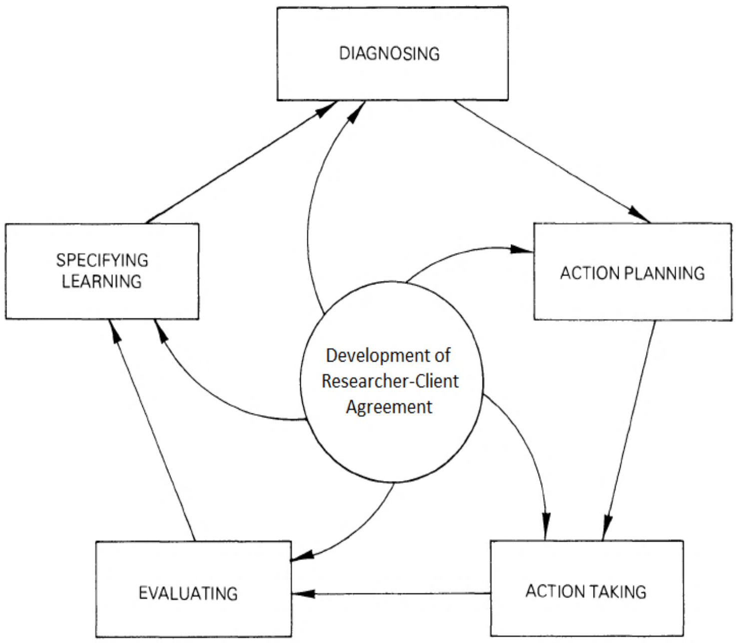


Figure 11: Cyclical Model of Action Research – adopted from Susman and Evered (1978, p.588)

At the diagnosis stage, problems are identified or defined first and during action planning, following which alternative pathways of actions are considered towards solving the problems. Following this, at the stage of action taking, a course of actions is selected and operationalised. At the evaluation stage, the consequences of the action taken are studied. Finally, at the learning stage the general findings are identified.

The third principle revolves around use of theory in action research. McKay and Marshall (2001) assert that action research is not research if it does not relate to theory. However, McTaggart (1991) and Bunning (1995) disagree on the necessity of theory. Despite this, the prevalent argument is that the researcher's thoughts, insights and ideas have to be organised through a theoretical framework to underpin and support the research, even if the precise theory to emerge is not known at the beginning (Davison et al., 2004).

The fourth principle, i.e. change by means of action, essentially refers to the key role of action in the developmental agenda towards changing the status quo and the unsatisfactory situations (Hult and Lennung, 1980). If the unsatisfactory situations did not change, the scenario might suggest that (a) there is no significant problem, (b) the specifically-planned remedial action has failed to deal with the pressing issues, or (c) the consideration of other practically political barriers has been ignored in the client-researcher agreement (Davison et al., 2004).

The last principle of CAR emphasises learning via reflection. According to Lau (1997), the most crucial activity of action research is to specify the learning gained from the actions taken. Through reflection on the outcomes of research as well as the method of reaching such outcomes, the researcher would fulfil his/her responsibilities towards the organisation concerned and the research community. This reflection would offer a report on the lessons learned, specifying what the research infers for the practice in terms of improvement as well as for the theory in terms of advancement of the boundaries of knowledge.

A number of criteria for CAR are designed by Davison et al. (2004), using the five principles. Conducting a review of the issues and challenges encountered in CAR, Davison et al. (2012) find no report of methodological problems, yet they mention four accounts of issues when such principles are employed in organisations. They reveal that:

First, after the initial stage, i.e. diagnosis, it is difficult to develop a clear-cut understanding of the situations in the organisation. Second, no strongly-practical explanation exists to lead the operations, i.e. to operationalise the strategically-intended transformations, though the operation/action planning is based on theory. Third, rigorous evaluation to produce effective operations is difficult. Fourth, whilst theory is important in CAR, it is not easy to certify the infusion of theory in every activity of the process cycles. To respond to such criticism and issues, Davison et al. (2012) introduces two types of theories relevant to CAR, namely focal theories and instrumental theories. According to them, focal theories are those that provide the intellectual foundation and the rationale of change based on action, e.g. theory of planned behaviour (Ajzen, 1991) or theory of adaptive structuration (DeSanctis and Poole, 1994).

In comparison, instrumental theories discuss and explain the phenomenon in focus (e.g. Angeles, 1992). They describe the means and the processes that approve focal theories or analyse the activities, e.g. micro-theory (Markus et al., 2002) and theory for analysing (Gregor, 2006). Hence, it is perceived that instrumental theories underpin the rigour of CAR. In addition, the instrumental theories can mediate between researcher and decision makers in the organisation.

With a focus on analysis of activities towards addressing the problems, these theories can also reduce stakeholders' tensions and misunderstanding. As Hambrick (2007) explains, these theories facilitate us in reaching an understanding through organising our thoughts and creating rational explanations. Being practical, instrumental theories closely capture and match with reality (Weick, 1995).

Moreover, instrumental theories are designed to complement the focal theories, because focal theories are less likely to resolve the issues completely. In practice, according to Davison et al. (2012), instrumental theories are selected at all five stages of the research.

With these arguments on the rationale of focal and instrumental theories, Davison et al. (2012) enhance the previously-developed criteria to strengthen the rigour in CAR, further incorporating the role of theory in action research (Table 12). These principles and criteria will be used to examine and reflect on how rigorously the action research processes have been carried out in this research.

P1. Principle of a researcher-client agreement
C1a. Did both the researcher and the client agree that CAR was the appropriate approach for the organizational situation?
C1b. Was the focus of the research project specified clearly and explicitly?
C1c. Did the client make an explicit commitment to the project?
C1d. Were the roles and responsibilities of the researcher and client organization members specified explicitly?
C1e. Were project objectives and evaluation measures specified explicitly?
C1f. Were the data collection and analysis methods specified explicitly?
P2. Principle of the cyclical process model
C2a. Did the project follow the cyclical process model or justify any deviation from it?
C2b. Did the researcher conduct an independent diagnosis of the organizational situation?
C2c. Were the planned actions based explicitly on the results of the diagnosis?
C2d. Were the planned actions implemented and evaluated?
C2e. Did the researcher reflect on the outcomes of the actions?
C2f. Were this reflection followed by an explicit decision on whether or not to proceed through an additional process cycle?
C2g. were both the exit of the researcher and the conclusion of the project due to either the project objectives being met or some other clearly articulated justification?
C2h. How was the independent diagnosis of the organizational situation conducted?
C2i. Which instrumental theories did the researcher use?
C2j. How were these theories selected?
C2k.How did these theories support the identification of the focal theory used to guide the changes?
C2l. Post-operation, did the researcher reflect on the instrumental theories used and their suitability?
P3. The principle of theory
C3a. Were the project activities guided by a theory or set of theories?
C3b. Was the domain of investigation, and the specific problem setting, relevant and significant to the interests of the researcher's community of peers as well as the as well as the client?
C3c. Was an instrumental theory used to derive the causes of the observed problem?
C3d. Did the planned actions/operations follow from this instrumental theory?
C3e. Was the focal theory used to evaluate the outcomes of the operational solution?
C3f. Did a focal theory emerge from the situation or during the problem diagnosis?
C3g. Was this focal theory acceptable to both client and researcher?
C3h.What role did instrumental and focal theories play with respect to the diagnosis and the action planning?
C3i. Were these theories evaluated for their applicability to the organizational context, considering current organizational practices?
C3j. Did both the researcher and the client undertake this evaluation?
C3k. Were theoretical explanations for the current organizational problem situation evaluated and reflected upon?
C3l. Did the researcher reflect on the focal theory used and its ability to predict the change outcomes?
P4. The principle of change through action
C4a. Were both the researcher and client motivated to improve the situation?
C4b. Were the problem and its hypothesized cause(s) specified as a result of the diagnosis?
C4c. Were the planned actions designed to address the hypothesized causes?
C4d. Did the client approve the planned actions before they were implemented?
C4e. Was the organization situation assessed comprehensively both before and after the actions/solutions?
C4f. Were the timing and nature of the actions taken clearly and completely documented?

P5. The principle of learning through reflection
C5a. Did the researcher provide progress reports to the client and organizational members?
C5b. Did both the researcher and the client reflect upon the outcomes of the project?
C5c. Were the research activities and outcomes reported clearly and completely?
C5d. Were the results considered in terms of implications for further action in this situation?
C5e. Were the results considered in terms of implications for action to be taken in related research domains?
C5f. Were the results considered in terms of implications for the research community (general knowledge, informing/re-informing theory?
C5g. Were the results considered in terms of the general applicability of CAR?

Table 12: Rigor and Quality Criteria for Canonical Action Research based on the Five Principles (Davison et al., 2012)

3.2.3. Reflection and Learning from Criticism of AR and CAR

Whilst Davison et al. (2012) strive to overcome the challenges of action research through the five principles as well as focal and instrumental theories, the model has been developed and used in the field of information systems and software development. Arguably, in social science, including the management field of study, developing a clear understanding about the organisational situation as well as identifying and defining organisational issues depend on understanding the context and the complexities attached to said situation. In a sense, problems in social contexts are perceived as being interconnected, systemic and generally of a tacit nature. Therefore, developing solutions requires a great many contextual considerations. Further, the context is what makes the reflection meaningful. Reflection on the results that are driven from evaluation is what makes the cycle momentous because it produces the lessons learned. This is where the scientific knowledge (produced through research) is brought about to support practice. Although developing researcher-client agreement is a reasonable step towards recognition of the context, it appears that principles and criteria offered in CAR can be easily reduced to mere a checklist of questions and are not sufficient in social contexts. On the other hand, with systems thinking, as new ways of thinking, the soft systems methodologies are built around contextual conditions, components of the phenomenon and the role of researcher. They are powerful for systems design and organisational development. Soft systems methodologies use relations and interactions to investigate where the heart of the problems lies. This can narrow down the issues without breaking them into separate components. It also contributes to finding the most relevant methods, techniques or solutions for the problems in the organisation and can respond to criticism of the relevance of the solutions in the action research.

3.2.4. Soft Systems: Checkland's FMA Account of Action Research

Checkland (1985) offers a soft systems view on action research which reveals an organised use of rational thought. Later, in 1995, it was refined to shape and model any research. This soft account of action research is illustrated in Figure 12.

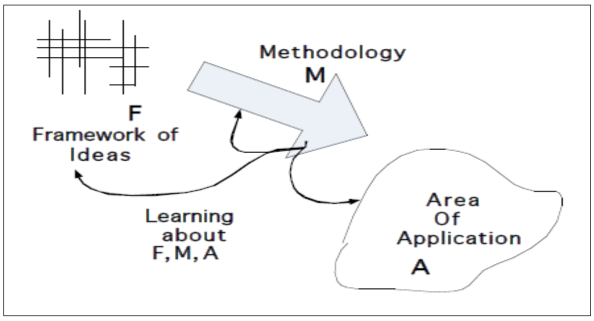


Figure 12: FMA Soft Systems Account of Action Research (Checkland, 1985)

Figure 12 hints at the significance of the researcher's roles in explicating the framework of ideas (F) based on which the research methodology (M) is established. These F and M help the researcher to understand and interact with the case in the area of application (A). According to Checkland (1985), the types of learning that occur in the FMA soft-account of action research relate to the nature of three scenarios. First, the researcher is learning about the area of concern, which might also resemble the area of application. Here, understanding the context and situational experience play a major role in defining the area of concern or area of application. The second type of learning relates to the ways actions occur. The third kind of learning refers to the conceptual framework based on which the actions are established. West and Stansfield (2001) analyse learning types within Checkland's FMA model and state that:

> *"Representation of the notion of understanding and learning coming about as a result of reflection upon the practical interaction resulting from a collaborative research study in the tradition of action research. He goes further than authors such as Susman and Evered (1978) and Hult and Lennung (1980), who describe the cycle of action and learning inherent in action research" (p.6).*

Central to the FMA soft account of action research is the cycle of actions and learning. This, therefore, puts forward a counter argument to those who criticise FMA as being rigid on setting the framework of ideas at the beginning and being something unchangeable or static.

3.2.4.1. Framework of Theories (F)

The framework of theories offers meaning and clarifies the findings and lessons learned based on the context of the research. It shows awareness of the theoretical basis of the methodology and provides a frame of reference through which the researcher can reflect, interpret, evaluate the situations and move forward. It is very relevant to observe that the researcher adapts or develops this framework of reference as the research proceeds (Holwell and Checkland, 1998). Checkland (1995) states that:

> *"… but the literature of action research … was felt to be seriously deficient in one important respect. If descriptions of action research were to be more than merely anecdotal accounts of what had happened, it seemed an essential requirement that the researcher declare in advance the intellectual framework within which knowledge in the research situation will be defined. In other words, the researcher must set out the epistemology in terms of which findings will be expressed. … Accounts of action research without even the ghost of an analytical framework are no more than anecdotes" (p.2).*

Klein and Myers (1999) also refer to the framework of theories as a base for defending the research against being merely anecdotes. Clarifying such an intellectual framework of theories can also assist others in figuring out why the researcher has made particular decisions as well as any changes in the decisions said researcher has made in different scenarios whilst carrying out the research. Further, West and Stansfield (2001) argue that declaring the framework of theories provides more rigor to the action research; indeed, they defend the research and resist the accusation of those who claim that things are made up along the way. According to Holwell and Checkland (1988), such rigour would also better withstand the criticism from positivists.

3.2.4.2. Methodology (M)

According to Hughes and Sharrock (2016), in order to understand the nature of theories chosen for the research, the researcher has to inspect his/her own ontological and epistemological positions. For the purpose of the present research, these positions have been clarified in Section 3.1.1.1 and Section 3.1.1.2. The methodology embodies in itself the framework of theories (F). Hence, the adopted methodology is to be consistent with the ideas that underpin the theoretical framework so as to provide momentous reflections on the actions, findings and the lesson learned. Methodology (M) as Checkland and Holwell (1998) point out, is used to study research questions/themes that are relevant to the real-life problems. It is also important to note that the related concepts and materials are analysed and presented in this research in a way that is understandable for the practitioners. Closely linked to research positions in terms of ontology and epistemology, the consistency and relevance of the proposed methodology are checked using the framework of theories. The researcher dealt with this task in Section 2.4.1 in the literature review chapter, where the feasibility of the combinative perspective of VSM and SNA for the process of knowledge sharing was discussed. In addition, the choice of a combination of action research methods was discussed in Section 3.2.1. The combination of CAR and FMA was justified in Section

3.2.5. Data sources, collection methods, and tools for analysing the data are also presented in Section 3.2.5.1.

3.2.4.3. Area of Application (A)

For an action/operational research study, a significantly important aspect is to find and figure out the area of application, where there is a real-life problematic situation which needs to be changed. Here, the purpose is not to sell some research methods, but to find a deep and complex problematic situation and a desired context in which the research questions can be investigated using the framework of theories and the methodology. However, according to West and Stanfield (2001), choosing the case purely and merely based on an organisation's willingness to cooperate might not be appropriate. There should be a genuine interest in the research on the part of the organisation. In the same way, the researcher should have a genuine concern about, or interest in addressing, the issues/problems and the improvement in the situation through change and development. Therefore, the area of application would not be commensurate to a testing scenario for the research. In fact, the basic requirement of action research is collaborative learning through participation and, as Greenwood and Levin (1998) explain, a balance should be reached among research, participation and action. West and Stanfield (2001) further discuss that collaboration is very important in a sense that it provides validity and appropriateness to the action research as a research strategy. If collaborating organisations were to merely offer a scenario or field for study, then a researcher's efforts would not be considered as action research.

3.2.5. SCOR: A Combinative Methodological Framework based on FMA and CAR

In the arena of learning, there are two key aspects in Checkland's FMA soft model of action research that go beyond Susman and Evered's (1978) model. First, it clearly emphasises learning about the area of concern/application, which is directly linked to learning about the context. Second, it relates to learning within (as well as learning about) the process of research on the phenomenon. Hence, a combination of FMA and CAR will benefit from features of both, throughout the process of action learning. This combination provides a scenario for double-loop learning (learning and learning how to learn) that resembles an organisational cybernetic perspective on the process of conducting the research for the researcher. Since the context of this research relates to communities of learners and the aim is to develop the skills and competencies of the learners for performance improvement, the application of the viable system model will also provide the organisational cybernetics scenarios throughout the process of research for the learners in their own process of learning as well as learning how to learn. Clearly, there are learning interdependencies between research level, learner level and learning management level. Therefore, it is possible to argue that the combination can deal with the complexities and plurality of levels and roles. The researcher in this study uses Checkland's FMA soft-model of action research and combines it with the CAR hard-model, structuring the research model in such a way as to benefit from both soft and hard science. This combination can provide a dynamic scene for the multi-methodology to inform the research and practice.

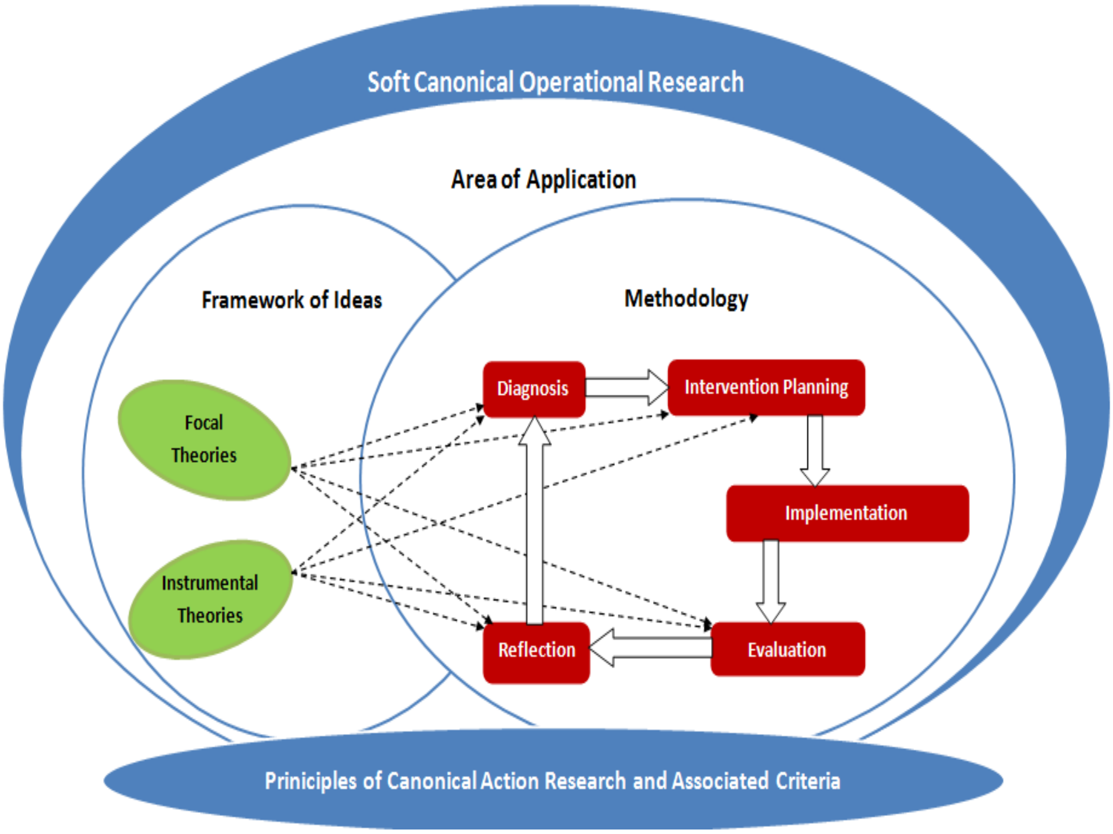


Figure 13: The SCOR Multi-Methodological Framework of this research

With the above explanation on the benefits of combining FMA and CAR, Figure 13 presents the Soft Canonical Operational Research (SCOR) framework model for this thesis. Based on said framework, the researcher first explores the area of application in order to understand the contexts and the problems that require solutions. The next stage is about deeper investigations to diagnose the situations and to learn about the underlying circumstances or conditions from which the issues and concerns emerge. Having diagnosed the situation, the third stage is about planning for an effective intervention using the framework of ideas (focal and instrumental theories). The fourth stage relates to the actual implementation of intervention, which will mostly be descriptive and will explain what happened in the process. Stage 5 refers to assessment and evaluation of the impacts that intervention has on the situation of concern. The final stage of the first cycle is about reflection and the learning that emerges from the processes in previous stages. The second cycle of action research then brings forward the learning from the first cycle. It starts from the diagnoses stage and continues to the reflection again.

3.2.5.1. SCOR Methodological Framework: Data Sources, Collection Methods/Tools and Data Analysis

According to Yin (1994), multiple sources of data enable data triangulations and further ensure the validity and reliability of the research. This research employed both primary and secondary sources of data, which included maths workshop observations notes, systemic solution sessions, SNA questionnaire, educational records/archives, meeting notes, interviews, and online APS-Maths knowledge network on Facebook[1].

In terms of sample size, Patton (2002) reveals that "there are no rules for sample size in qualitative inquiry. Sample size depends upon what you want to know, the purpose of the inquiry, what's at stake, what will be useful, what will have credibility, what can be done with available time and resources" (p.244). For this research, which aimed to facilitate students' knowledge sharing and skills development, the sample size of the first cycle comprised 52 learners (see Section 4.2.3.1.3.1 and Section 4.2.3.1.3.2). The second cycle contained 49 learners participating in the research (see Section 4.3.3.1.1.1 and Section 4.3.3.1.1.2). Hence, the total sample size was 101 students. The total population included 700 learners in the two cohorts of academic years, each representing a cycle for the soft canonical operational research. This accounts for 344 students in year 2015-16 (see Section 4.2.1.1) and 356 students in year 2016-17 (see Section 4.3.1.1).

In addition, four interviews were conducted. The contents of these interviews are used to generate insights into, and understanding of, the meta-system and the meta-systemic issues. The interview questions were designed based on Espinosa and Walker's (2011) meta-systemic questions (see interview questions in Appendix 9).

[1] It is important to note that the online APS-Maths knowledge network on Facebook was designed based on a strategy that participants decided upon at the time of participation in this research and hence it is a dynamic source of data that emerged within the process of this research. It is a private group on Facebook where participants did add themselves or the researcher added them to the group in order to receive the real-time information about the action research sessions (maths extra sessions) so they could attend. It can therefore be considered as a coordination spot for the researcher/change maker/observer. It also served as an online space where experiential learning in a collaborative way could happen (see Chapter 4 for full details).

The research starts with an investigation of the area of application/concerns. Table 13 shows the sources of data collection, the methods/tools, and the data analysis methods used (including relevant theories and steps).

Area of Applications/Concerns	
Data Sources, Collection Methods and Tools	Invite for the solutions, Meeting notes, Previous APS-Maths Performance Results, Interviews, HE Industry Reports, UK Secondary Education maths performance records
Data Analysis Methods	Thematic Analysis (Attride-Stirling, 2001): 1. Code the materials (a) Dissect the texts into text segments 2. Finding the Themes (a) Abstract themes from text segments (b) Refine Themes 3. Constructing Thematic Network (a) Arrange themes (b) Select Basic Themes (c) Rearrange into Organising themes (d) Find the global themes (e) Illustrate as Thematic Network 4. Exploring and Describing the Thematic Network (a) Explore the Network (b) Describe the Network 5. Summarising the Thematic Network 6. Interpreting the Patterns

Table 13: Area of application – data collection methods and analysis

According to Attride-Stirling (2001), the construction of a thematic network is not affected by the method which is chosen to code the data. The research question/specific topic, the theoretical interest and the issues which arise in the texts can be a guide in choosing the coding method. He mentions that:

> *"The codes in the coding framework should have quite explicit boundaries (definitions), so that they are not interchangeable or redundant; and they should also be limited in scope and focus explicitly on the object of analysis, in order to avoid coding every single sentence in the original text. This is an important interpretative step, but the fun doesn't really begin until this stage has been completed.*

In this research, the data will be coded based on two broad criteria concerning the state of skills development at the research site. These criteria relate to the environments that affect the strategies of the research site, and are (1) Higher Education Market, and (2) Secondary Maths Education (see Section 4.1.2.1.1 and Section 4.1.2.1.2).

The next phase is the diagnosis stage, in which key issues of the internal context would emerge. In order to analyse the data at this stage, the system in focus and system's identity need to be clarified. The surest way to discover/recognise what the system actually is can be through expressing what the system does. Normally, an identity statement is built up with participation from stakeholders and enables them to capture the interplay between the values/meanings that they ascribe to the systems. According to Espejo et al. (1999), the identity makes the field/space in which stakeholders agree to take the challenge of viability, more visible. The researcher adapts to Espejo et al.'s (1999) TACOI, which is a soft-OR tool. Through this tool, the nature of intended transformation, actors, suppliers, customers, owners and interveners are elucidated (see Section 4.2.1.2.1). In addition, Espinosa and Walker's (2013) meta questions are used to map the issues (see Section 4.2.1.2.2). Further, ethnographic observation is employed to accommodate Crossley (2010) on qualitative SNA (see Section 4.2.1.2.3 and Section 4.2.1.2.4 as well as Section 4.3.1.2.1 and Section 4.3.1.2.2).

Diagnosis stage	
Data Sources, Collection Methods and Tools	Information from Area of Application, Ethnographical Observations, Workshop facilitation notes, Interviews, Student Streaming Data, First Semester Attendance and Performance Results

Data Analysis Methods	**Viable Systems Diagnosis (Beer, 1985; Espinosa and Walker, 2013):**
	• Identifying system in focus and system's identity
	    • Identifying System 1
	    • Identifying meta-system
	• Illustrating the network map of meta-system
	• Mapping issues in System 1
	    • Using meta-systemic questions relevant to System 1
	• Mapping issues in the meta-system
	    • Using meta-systemic questions relevant to system 2, 3, 4 and 5
	• Interpreting the issues
	Qualitative SNA - Describing Ethnographic Observations :
	• Coding qualitative data
	• Exploring and Identifying the processes in System 1
	• Describing the qualitative processes in System 1
	• interpreting the processes in System 1
	Quantitative SNA - Graphic Description by UCINET :
	• Coding the quantitative data
	    • Clusters: Visual illustrations of System 1 quantitative data
	• Interpreting the issues in system 1

Table 14: Diagnosis Stage - Data collection methods and analysis

After the diagnosis stage, the plans of actions and the design of the actions/solutions matter. The action/operation design stage uses three main theories. Beer's (1972) performance measurement is used to analyse the performance of the past three years (see Section 4.2.2.1.1 and Section 4.3.2.1.1). Nahapiet and Ghoshal's (1998) social capital dimensions are also used to relate to a more effective way of managing social capital (see Section 4.2.2.1.2 and Section 4.3.2.1.2). In addition, the domains of viable knowledge devised by Achterbergh and Vriens (2002) are used for creating a skills development method note (see Appendix 2) to structure the operational processes in the classroom (see Section 4.2.2.1.3 and Section 4.3.2.1.3).

Action/Operation Planning and Design Stage	
Data/Information Sources	Performance results of Previous years, Attendance results, the collective of issues and categories identified in the first stage.
Planning and Design Methods	**Quantitative analysis of Exam Performance (Beer, 1972)** • Finding the Actuality of system in terms of KPI of Exam Success • Finding the Capability of system in terms of KPI Exam Success • Finding the Potentiality of system in terms of KPI of Exam Success **Considerations for Social Capital Dimensions (Nahapiet and Ghoshal, 1998)** • Relating to cognitive, relational and structural capital through overall students' attendance **Domains of Viable Knowledge (Achterbergh and Vriens, 2002)** • Relating to and interpreting the 31 domains of viable knowledge through creating a method note

Table 15: Action Planning Stage: Data Sources and Planning Methods

The implementation stage (see Section 4.2.3.1 and Section 4.3.3.1) follows the steps in the following table. Appendix 1 provides the method note (designed based on 31 domains of viable knowledge). Appendix 2 relates to the introduction to basic VSM concepts. Appendix 3 is the motivational note. Appendix 4 and Appendix 5 address the team and individual feedback forms.

Action/Operational Implementation Stage	
Operational Plan 3	**Creating a knowledge network in tutorials or in extra maths sessions** **1) Activities of Week 1:** a) Teams assembly based on maths knowledge level b) Defining Gaols and Identity c) Getting to know the method of collaborative knowledge sharing and Introducing the viable system model d) Justification on the expected benefits for students with different maths levels e) Defining and agreeing on underlying rules for the sessions **2) Activities of Week 2 and Onwards:** a) Teams assembly based on maths knowledge level b) Facilitating maths question solving practices in teams through collaborative knowledge sharing, according to 31 domains of viable knowledge (method note) c) Gathering the individuals' and teams' feedback forms d) Weekly reflection on the feedback forms and monitoring the maths skills development e) Weekly Preparation/Printing the learning and practice materials based on the feedback forms

Table 16: Implementation Stage: Activities

The evaluation/assessment stage relates to the results of soft-canonical operational research. Four main types of evaluation are performed. These include: (1) analysis of final performance in maths (see Section 4.2.4.2.1 and Section 4.3.4.1), (2) assessment of change in maths skills level (see Section 4.2.4.2.2 and Section 4.3.4.2), (3) assessment of change in maths knowledge network (see Section 4.2.4.2.3 and Section 4.3.4.3), and (4) analysis of strategy development (see Section 4.3.4.4).

Evaluation and Assessment Stage	
Assessment and findings of Operational Plan 3 (Maths knowledge Network)	**Impact of creating a knowledge network in tutorials or in extra maths sessions** **1) Analysis of maths exam success performance** • Quantitative comparison and Statistical graphic technique **2) Assessing the change in maths skills level** • Correlation and Regression Analysis • Analysis of fluctuations in the dynamic process of skills and confidence development • Analysis of fluctuations in satisfactions on support received **3) Assessing the change in maths knowledge network (using UCINET)** • Graphic technique of SNA • Quantitative SNA • Network level measures • Network Density • Network Cohesion • Average distance in the network • Individual level measures • Degree centrality • Eigenvector closeness • Flow Betweenness **4) Results of assessing developments in strategies** • Strategy analysis through reflection on relevant theories

Table 17: Evaluation Stage: Assessment and Findings

The final stage in each cycle is the reflection and learning stage. As shown in the next table, the learning from each stage will be specified (see Section 4.2.5 and Section 4.3.5).

Reflection and Learning Stage	
Reflection and Learning from Stage One	Learning from Systemic Diagnosis
Reflection and Learning from Stage Two	Learning from Action Planning and Design
Reflection and Learning from Stage Three	Learning from Implementing the Actions/Solutions
Reflection and Learning from Stage Four	Learning from Evaluation and Assessment

Table 18: Reflection and Learning Stage

3.3. Chapter Conclusion: Assessing the Design of Multi-Methodology

In order to assess the design of the multi-methodology, the researcher refers to Mingers and Brocklesby's (1997) framework. This framework summarises various possibilities for mixing the methodologies. It assists in dealing with real-world perspectives and the richness of viewpoints more effectively, and therefore better facilitates the different stages of research. It considers the philosophical assumptions, as well as the feasibility of the cultural and rational aspects of multi-methodologies. Mingers and Brocklesby's (1997) framework systematically turns the multi-methodology into its detachable components and reveals the proportional strength of various methodologies.

Reflecting on the philosophical orientation of the research laid out in Section 3.1. and the design of the SOCR multi-methodology in Section 3.2., the CAR provides its strengths on covering material/objective aspects at all four stages of the framework.

Mingers and Brocklesby (1997) state that soft system methodologies attend to the personal/subjective level at all four stages of the framework. In addition, these methodologies also cover social, personal and material aspects at the appreciation stage.

VSM supports covering three stages of analysis, assessment and action at social and material levels. Therefore, based on the mapping of the SCOR multi-methodology in Mingers and Brocklesby's (1997) framework, it is safe to suggest that the combination of methodologies and methods in the SCOR multi-methodology covers all stages and levels in Mingers and Brocklesby's (1997) framework (see the green areas in Table 19 and Table 20).

<table>
<tr><th colspan="6">Dimensions of SCOR multi-methodology on Mingers and Brocklesby's (1997) framework</th></tr>
<tr><th>SCOR Stages</th><th>Mingers and Brocklesby's Framework</th><th>Social World</th><th>Personal World</th><th>Material World</th><th></th></tr>
<tr><td>Area of Application</td><td rowspan="2">Appreciation of</td><td>External Environment: Competitive Relations, Patterns/trends of current situation</td><td>External Environment : Individual positions, circumstances and situations</td><td>External Environment : Resources, Processes, and Infrastructure</td><td rowspan="7">Framework of Ideas:
Focal Theories and Instrumental Theories</td></tr>
<tr><td rowspan="2">Diagnosis</td><td>Internal Context: Norms/ codes of Practices, Governing rules, Power relations</td><td>Internal Context: Varied perceptions on interactions and relations; Different ideas on identity</td><td>Internal Context : Resources, Processes, Circumstances</td></tr>
<tr><td>Analysis of</td><td>Social interaction problems, learning issues, Power balance, Performance issues; Structural issues, Communication</td><td>Varied knowledge type; different skills level; differing performance levels</td><td>Underlying causal mechanisms; Misalignment of issues and solutions</td></tr>
<tr><td>Action Design</td><td>Assessment of</td><td>Realistic ways to change the power and structural distances; Viable methods that enable communication and collaboration; Feasible approaches to collective knowledge sharing, experiential learning, skill development and performance improvement</td><td>Alternative concepts and constructs</td><td>Alternative ways of organisation; Alternative ways of arranging the structure</td></tr>
<tr><td>Operation/ Action</td><td>Action to</td><td>Orient/empower learners towards goals/identity; Facilitate collaborative knowledge sharing and learning/practicing among learners; Develop learners' skills; Improve their performance</td><td>Create consensus; Generate personal determination and motivational resources in developmental experiences</td><td>Choose and apply best alternative</td></tr>
<tr><td>Evaluation</td><td>N/A</td><td>Change in collective skills level; Change in collective performance; Change in motivation level; Change in collective developmental strategies; Change in knowledge network; Emergent and unplanned outcomes</td><td>Change in personal understanding and insights; Change in individual skills level; Change in personal performance</td><td>Denser, more interconnected network; Improved performance</td></tr>
<tr><td>Reflection</td><td>N/A</td><td>Organisational understanding and reflective practice</td><td>Personal insights and reflective practice</td><td>Reflective practice</td></tr>
</table>

Table 19: Dimensions of SCOR Multi-Methodology in Mingers and Brocklesby's (1997) Framework

Mapping SCOR multi-methodology on to Mingers and Brocklesby's (1997) Framework					
SCOR Stages	**Mingers and Brocklesby's Framework**	**Social World**	**Personal World**	**Material World**	
Area of Application **Diagnosis**	**Appreciation**	Attride-Stirling's (2001) Thematic analysis; Espejo's (1999) TASCOI; Rogers's (1969) facilitation theory	Attride-Stirling's (2001) Thematic analysis; Espejo's (1999) TASCOI; Rogers's (1969) facilitation theory	Attride-Stirling's (2001) thematic analysis of external Context	**Framework of Ideas: Focal Theories and Instrumental Theories**
Diagnosis	**Analysis**	Beer's (1985) viable system diagnosis method; SNA (qual and quant); Nahapiet and Ghoshal's (1998) three dimensions of social capital Theory; Beer's (1972) viable system theory for Performance measurement; Achterbergh and Vriens's (2002) domains of viable knowledge Dragoni et al.'s (2009) leadership development	Beer's (1985) viable system diagnosis method; SNA (qual and quant); Nahapiet and Ghoshal's (1998) three dimensions of social capital Theory; Beer's (1972) viable system theory for Performance measurement; Achterbergh and Vriens's (2002) domains of viable knowledge Dragoni et al.'s (2009) leadership development	Beer's (1985) viable system diagnosis method; SNA (qual and quant) for analysis of internal Context	
Action Design	**Assessment**	Feasibility discussion	Feasibility discussion	Feasibility discussion	
Operation/ Action	**Action**	Implementation	Implementation	Implementation	
Evaluation	**N/A**	VSM Performance assessment, Statistical Analysis; Evaluation of gradual change in Skills Development; SNA; Developments in network strategies	Change in personal understanding; Change in individual skills level; Change in personal performance	Improved performance	
Reflection	**N/A**	Reflective practice and learning on diagnosis, action planning, implementation and evaluation	Reflective practice	Reflective practice	

Table 20: Mapping SCOR Multi-Methodology onto Mingers and Brocklesby's (1997) Framework

Chapter 4: Soft Canonical Operational Research (SCOR) Case Studies

4.0. Introduction

This chapter serves to provide the process of data collection and analysis throughout the two cycles of Soft Canonical Operational Research (SCOR). Each cycle will be presented as a soft-OR case study with multiple embedded actions/activities within a business school in a UK Higher Education Institution (HEI). The journey of data collection started with a call for a systemic solution from a business school of a UK-based university which was seeking to improve the academic and professional skills of its first-year undergraduate students. This chapter will refer to the business school as BSUKU so as to protect the anonymity of the research site.

Both primary and secondary sources of data were established and data was acquired as discussed in Chapter 3, Section 3.2.7 and Section 3.2.8. These multiple sources of data, according to Yin (1994), enabled data triangulations and further ensured the validity and reliability of the findings in the SCOR cycles. The data analysis and findings of the first phase of the SCOR methodology, i.e. the area of application, will be presented first. This chapter then proceeds with the two research cycles, i.e. 2015-16 and 2016-2017; each of these is a case study, explained in Section 1 and Section 2, respectively. The chapter ends with reflection on this research.

4.1. Area of Application/Concerns

Finding the area of application/concerns in the SCOR methodology of this research is related to the analysis of the context/background. Table 21 shows the data collection tools and method of data analysis employed for this phase. Such an analysis enabled the researcher to gain a better understanding of the vicinity from which the issues and problematic situation stemmed.

Area of Applications/Concerns	
Data Sources, Collection Methods and Tools	Invite for the solutions, Meeting notes, Previous APS-Maths Performance Results, Interviews, HE Industry Reports, UK Secondary Education maths performance records
Data Analysis Methods	Thematic Analysis (Attride-Stirling, 2001): 1. Code the materials (a) Dissect the texts into text segments 2. Finding the Themes (a) Abstract themes from text segments (b) Refine Themes 3. Constructing Thematic Network (a) Arrange themes (b) Select Basic Themes (c) Rearrange into Organising themes (d) Find the global themes (e) Illustrate as Thematic Network 4. Exploring and Describing the Thematic Network (a) Explore the Network (b) Describe the Network 5. Summarising the Thematic Network 6. Interpreting the Patterns

Table 21: Analysis – Area of Application: Using Attride-Stirling (2001)

4.1.1. Process

After being sent an email on 10th August 2015 inviting her to come up with a systemic solution, the researcher (myself) made the first contact with the module leader at BSUKU in order to discuss the case. In a meeting arranged for 12th August 2015, the module leader introduced herself and gave a brief description of her role. She then provided the background information about the academic and professional skills module developed in the business school for first-year undergraduate students. She explained that students have three modules per semester in their first year. These modules are Business Environment, Organisational Behaviour, Marketing, Accounting and Finance, and Academic and Professional skills. The Academic and Professional skills module was studies in both semester 1 and semester 2. They took varied modules to be able to decide which route they will be specializing in the second and third year of their undergraduate degree. Although, students required different knowledge level of maths/stats for their second and third year, they all were taught the same level and depth of the maths topics including further maths in the module of academic and professional skills. This module was known as APS (worth 20 credits), and was being run from September of each year to June the next year, consisting of two parts. Its aim was to develop students' maths/statistics (quantitative) skills, as well as their writing (qualitative) skills. The module leader further discussed the concerning situations which had arisen in previous years. The key issues from the module leader's perspective were students' maths/statistics skills and their poor performance. According to her, this was despite the fact that most of the maths contents of this module had been taught in high school/secondary school education. The researcher also introduced herself and her professional capacities as a mathematician, as a systems analyst and as a development facilitator. Further, as an academic herself, she discussed her research on the systemic methods of knowledge sharing processes, as well as using social networks and the viable system model for this PhD thesis. Through discussions and negotiations, it was agreed that the researcher would analyse the situation and develop an action agenda and a systemic solution required for tackling the core problems in the APS module. The module leader also agreed that the researcher would collect the data from this project for her PhD dissertation. In order to assess and examine the width and extent of the situation and on the way to devising an action research and the systemic solution, the researcher decided to obtain a bigger picture of the phenomenon. Since the discussion was related to first-year undergraduate students, it was evident that the issues pertained to students who had been freshly admitted to the BSUKU. This brought to light the importance of investigating how students are admitted to universities and how universities deal with skills problems. Hence, the researcher analysed the UK HE reports along with additional materials. From the other side, since the contents of the APS module were similar to GCSE and A-level maths, it was beneficial to examine students' prior maths knowledge level. Therefore, the researcher extracted the data from UK student performance national percentage figures for GCSE and A-level grades. The data and materials related to the situation were then analysed based on Attride-Stirling's (2001) thematic analysis framework to provide a clearer picture of the phenomenon, i.e. the area of application/concerns.

4.1.2. Findings

Through analysis of the data, the researcher devised the basic, organising and global themes (see Figure 14). From a management perspective, the increased number of students and issues in their prior maths knowledge, as well as BSUKU's skills development strategy, were responsible for the concerning state of APS Maths at BSKU.

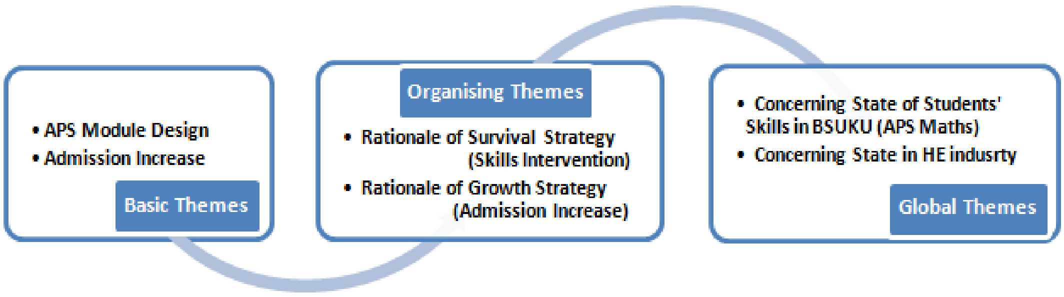


Figure 14: Area of Application – Basic, Organising and Global Themes (Attride-Stirling, 2001)

The following provides a brief of maths performance in previous years and looks at the concerning scenario from two perspectives, namely the HE industry market and secondary maths education. The two perspectives provided evidence to justify the reasons for the APS project and indicated the deeper roots issues.

4.1.2.1. Concerning State of Skills Development at BSUKU (APS Maths)

Analysis showed that despite the academic endeavours, BSUKU was facing alarmingly reoccurring failures in developing the maths/statistics skills of first-year undergraduate students. Table 22 illustrates the concerning increase in the rate of fail for three consecutive years.

Admission	Rate of Fail
2012-2013	16.25%
2013-2014	20.00%
2014-2015	26.15%

Table 22: Performance in Maths per year at BSUKU

This issue was considered as a bottleneck for the learning of other modules, since the skills developed in this module were highly required for the successful learning accomplishments in the year 2 and year 3 modules for any undergraduate degree at BSUKU. In fact, according to the module leader:

> *"A survey among lecturers who are teaching in year 2 and 3 shows that students are mainly struggling because they do not have the required maths skills. From students' perspective also, a survey suggests that those who spend time developing their maths skills at the start of their studies, find their time very well spent" (APS Module Leader, Meeting notes from 12th August 2015).*

Yet, the increasing decline in performance rate in APS Maths was interlinked with other strategic decisions at higher management levels of BSUKU. The issues were in turn rooted partly in the changes in the HE market (analysed in Section 4.1.2.1.1 below) and partly in secondary maths education (analysed in Section 4.1.2.1.2).

4.1.2.1.1. Higher Education Market Perspective

The analysis showed that, from one side, the UK government began to lift the admissions cap on students' numbers in 2012-13 and totally abolished this cap for undergraduate courses in 2015-16. From another side, the public funding was decreased and fee income was changed, as shown in Chart 3. With these changes, a new realm, i.e. a must-compete situation, surfaced for HEIs so as to survive as well as to grow and expand their market share. Hence, depending on the ranking (high-ranked, middle-ranked, low-ranked), universities adopted different strategies. As the Dean of BSUKU points out:

"A low- or middle-ranked higher education institution would for example seek to increase the admission numbers. This in turn ensures enough finance for the schools and compensates the financial cuts as well as retaining the market share" (Dean of BSUKU, 17th August 2016).

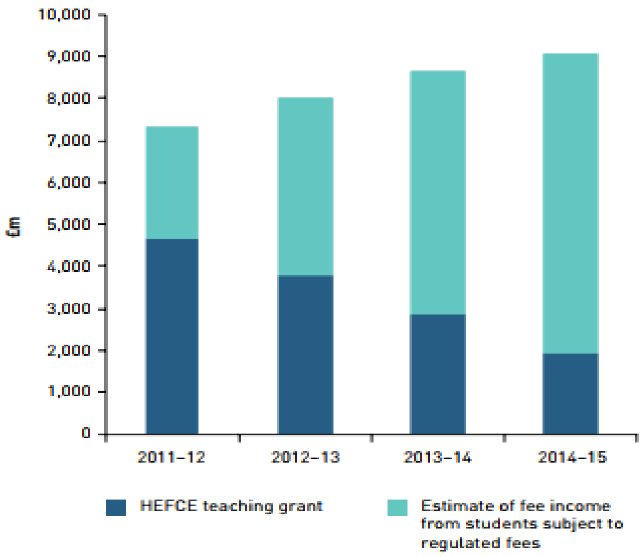


Chart 3: Public Funding and Fee Income (Universities UK, 2015)

The strategy at BSUKU was set to increase the number of students. Indeed, the implementation of this strategy is evident from the 300+ new undergraduate entrants per academic year at BSUKU. While many students are recruited via normal applications processes, there are always extra opportunities for recruiting more through clearing processes. In this arena, the entry requirements for the BSUKU undergraduate courses were not too strict, particularly with regard to maths. According to the website of this university:

> *"While we don't have a specified entry requirement in terms of GCSE Maths and English, some of our courses do have these as a requirement. Certain professional training courses (nursing, ODP, midwifery, teacher training, social work) have numeracy and/or literacy requirements placed on them by the external professional body" (University Website, 2015).*

The Dean of BSUKU also specifies his strategy for recruitment as:

> *"A part of my role is setting the level at which we accept students. So, if I set that level too low, you would have a trouble time ... If I set the level really really high, probably you would have much less to do. So, determining what sort of student to have is probably the most important thing that I do" (Dean of BSUKU, 16th June 2016).*

In addition, according to The Complete University Guide:

> *"Within the context of Clearing they may well go lower than the normal offer listed on their prospectus" (The Complete University Guide, 2015).*

The data of APS showed that GCSE F in maths is the lowest accepted grade at BSUKU. Although universities welcome and accept high achievers, it appears that students with lower maths and English grades can enrol easier in middle-ranked and low-ranked universities such as BSUKU.

4.1.2.1.2. Secondary Maths Education Perspective

The analysis of GCSE performance in UK secondary education showed not much promise in terms of maths. This meant that the solutions offered in the secondary education system for tackling the problems of GCSE maths performance had not yet yielded any progress. Chart 4 shows no improvements in maths performance since approximately the same percentages were reoccurring each year.

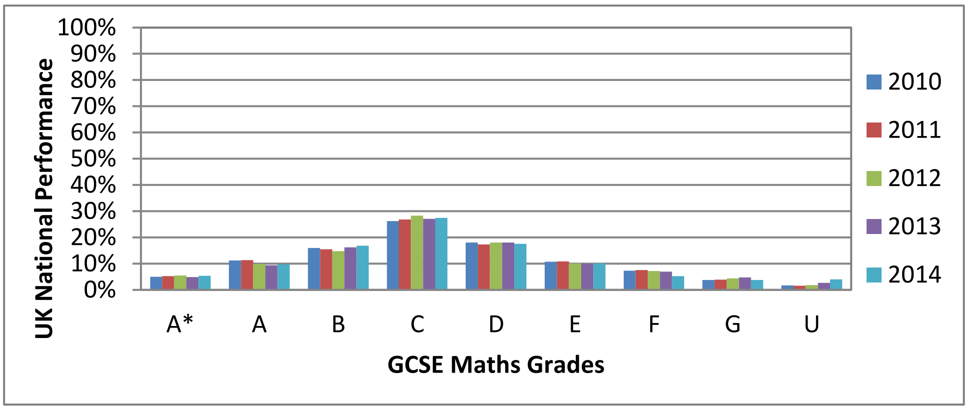


Chart 4: Secondary Education – GCSE Maths Performance in UK (Data: bstubbs.co.uk, 2015)

The trend in A-level maths also showed no improvements. It was evident that the percentage of A graders has decreased and the percentage of B and C graders has increased year by year (see Chart 5).

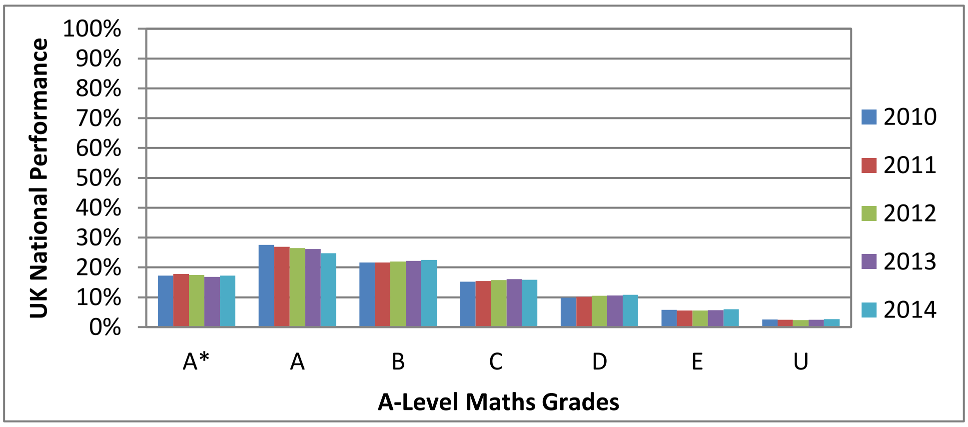


Chart 5: Secondary Education – A-Level Maths Performance in UK (Data: bstubbs.co.uk, 2015)

This suggests that the UK secondary education system is facing stagnant issues in developing/improving students' maths skills. Since the best graders are mainly absorbed by the best-ranked universities, such unsolved skills problems are mainly transferred into middle- and low-ranked HEIs. Faced with such challenges, universities employ certain intervening strategies. For this purpose, BSUKU designed and developed a compulsory Academic and Professional Skill (APS) module worth 20 credits, which aimed to equip first-year undergraduate students with both qualitative and quantitative capabilities and in particular quantitative (maths) skills. In doing so:

> *"Considering APS Maths as very strategic, the ultimate objective is to level up students' maths knowledge to a minimum through maths lectures, workshops, and using MyMathLab software" (Dean of BSUKU, 16th June 2016).*

4.1.3. Discussions

With reference to Attride-Stirling's (2001) framework for data analysis, Figure 15 shows basic, organising and global themes for area of application/concerns in the SCOR methodology of this thesis.

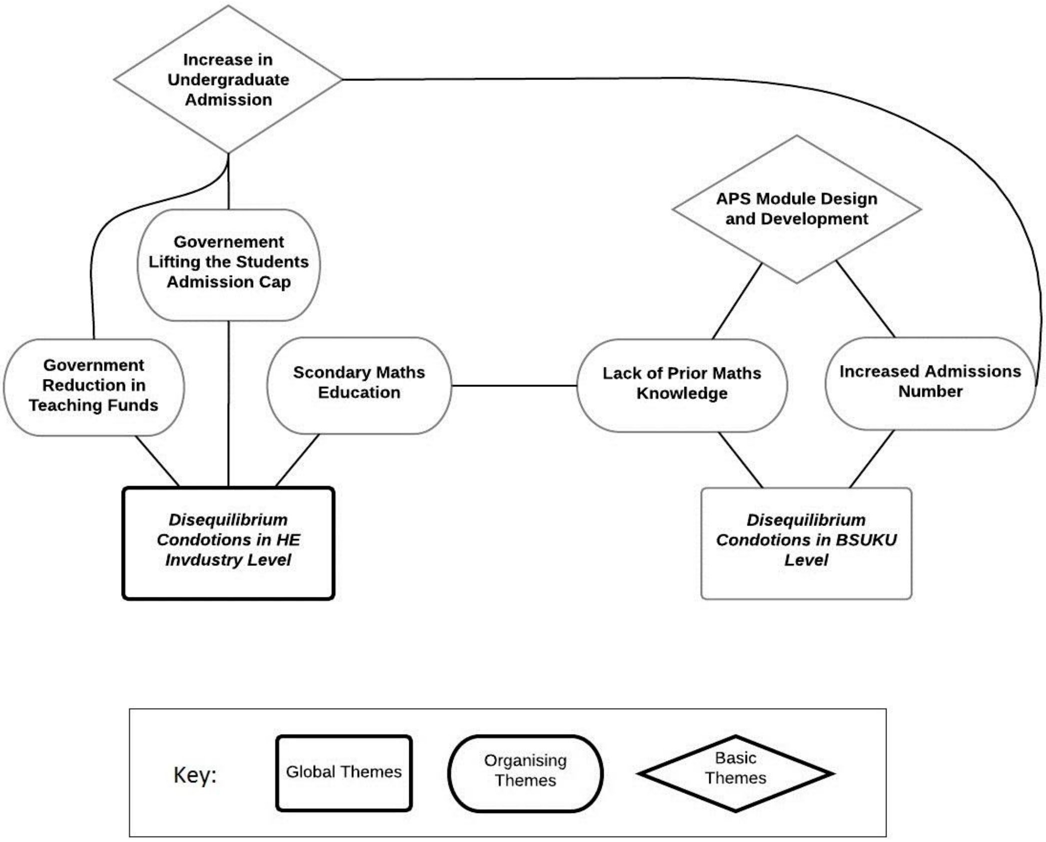


Figure 15: Area of Application/Concerns – Basic, Organising and Global Themes

According to McKelvey (2004), activities or phenomena that happen outside the norm of the context drive the system into an extremely dynamic state. In particular, in the social systems, as Lichtenstein (2000) puts it, the energy flux is embodied in new episodes that interrupt the existing order and supply the energy and driving force for a new order to emerge.

In this study, it is evident that major changes at industry level, such as lifting the students cap and reduction in universities' teaching funds, as well as the skills situation in secondary maths education, are fluctuations that generate an instable state, i.e. disequilibrium in the HE industry system. This also supplies the energy for the new order in the HE industry. A growth strategy, such as the recruiting of more undergraduate students by low- or middle-ranked universities, is considered as a new order in the system. As Meyer, Gaba and Colwell (2005) explain, a requisite for the emergence of the new order is the sustenance and continuity of the state of disequilibrium over an extended period of time in the system. This situation, as Chiles et al. (2004) suggest, represents the fluctuation dynamics in the system. Prigogine and Stengers (1984) propose that the new order emerges through fluctuation and hence is the core of the dissipative system structures. During major changes such as lifting the students cap and reduction in universities' teaching funds, along with facing unsolved maths skills problems that are derived from secondary education, the system is in a state which is far from equilibrium. Considering that the HE industry is an open system, these changes started in 2012 and the implementation has continued until the present day. At this level, lifting the students cap and reduction in universities' teaching funds, as well as the status of secondary maths education, have shaped the disequilibrium state. These basic and organising themes formed the HEIs-level disequilibrium whilst HEIs such as BSUKU themselves introduced perturbations within their own institutions through transformations such as increases in undergraduate admissions in order to compete in the external environment.

At the business school level, lack of prior maths skills and increased admission numbers are structurally coupled up and push the BSUKU undergraduate degree programmes into a disequilibrium state. Since this new situation in the HE industry (i.e. the environment in which BSUKU is operating) is paramount, consequently a new order in BSUKU undergraduate degree programmes has received the energy to emerge and sustain itself. Central to the emergence of the new order based on the theories of complex adaptive systems, is the creation and continuity of disequilibrium in the system (Lichtenstein and Plowman, 2009; Goldstein, 1986; Prigogine and Stengers, 1984; Schieve and Allen, 1982). Since the lack of prior maths skills and increased admission numbers are continuing, the disequilibrium in BSUKU has also become paramount. Hence, the design and development of the APS module in order to improve students' skills has become the new order in the BSUKU undergraduate programmes, with the aim of reaching a new equilibrium.

In addition, BSUKU can be considered as an energetically-open, yet operationally-closed system that follows its defined purpose and identity. A system's behaviour can also be explained via Beer's (1972) viability theory and Ashby's (1956) law of requisite variety. Prior to change in the HE industry, BSUKU could be described as a homeostatically-balanced entity in an equilibrium state between its own management and its external environment, subject to the law of requisite variety. The perturbations that came from the external environment (i.e. lifting the students cap and reduction in universities' teaching funds in the HE industry as well as the status of secondary maths education) are external varieties. These varieties are clearly greater than BSUKU's variety. To cope with the variety of the external environment, BSUKU must generate internal varieties, since according to Ashby (1956) only variety can absorb variety. In the other words, just as the impacts of lifting the students cap and reduction in universities' teaching funds as well as lack of prior maths skills (as incoming varieties) must be managed/reduced, so must BSUKU's outgoing managerial variety be enhanced through transformation. According to Beer (1972), each of the system's parts offers some varieties. However, it is the responsibility of intelligence (management level – system 4) to tap into such variety, to arrange it, and to select it. Hence, the intelligence is required to amplify and strengthen the most important choice. The adopted strategy for the management level at BSUKU was the design and development of the APS module. At this level, increased admission numbers and lack of prior maths knowledge shaped the disequilibrium state at BSUKU. These basic and organising themes formed BSUKU's disequilibrium whilst BSUKU itself offered perturbations within its own institution through changes such as the design and development of APS as a mechanism to (1) cope with increased admission numbers and (2) develop students' skill and capability due to lack of prior maths knowledge.

4.1.4. Conclusion

Up to this point, the researcher has explored the context and critical factors that have affected the situation at hand. It is evident that APS-Maths at BSUKU is the area of concern, with maths skills problems inherited from secondary education. Since there was three years of continuous increase in the rate of fail, the next step for the researcher was to examine BSUKU's implementation of the APS module. This will be discussed in the case studies of this research.

4.2. Section 1: First Cycle (2015-16) Case Study

This section of the SCOR methodology presents the development of the first case study. The SOCR methodology of this action research case study comprises five stages, namely diagnosis, action planning, implementation, evaluation and reflection/learning.

4.2.1. Stage 1: Diagnosis

At the stage of diagnosis, the researcher examined how the APS module is managed. With the insights/knowledge of the background which emerged from area of application (Section 4.1), the diagnostic analysis at this stage was to find the key issues and the complexities associated with the problems. This process enabled the researcher to gain a deeper understanding of the issues and the situation of the module. Table 23 shows the sources of information and data collection tools/methods, as well as the data analysis method for this stage.

First Cycle: **Diagnosis stage**	
Data Sources, Collection Methods and Tools	Information from Area of Application, Ethnographical Observations, Workshop facilitation notes, Interviews, Student Streaming Data, First Semester Attendance and Performance Results

Data Analysis Methods	**Viable Systems Diagnosis (Beer, 1985; Espinosa and Walker, 2013):**
	• Identifying system in focus and system's identity
	    • Identifying System 1
	    • Identifying meta-system
	• Illustrating the network map of meta-system
	• Mapping issues in System 1
	    • Using meta-systemic questions relevant to System 1
	• Mapping issues in the meta-system
	    • Using meta-systemic questions relevant to system 2, 3, 4 and 5
	• Interpreting the issues
	Qualitative SNA - Describing Ethnographic Observations :
	• Coding qualitative data
	• Exploring and Identifying the processes in System 1
	• Describing the qualitative processes in System 1
	• interpreting the processes in System 1
	Quantitative SNA - Graphic Description by UCINET :
	• Coding the quantitative data
	    • Clusters: Visual illustrations of System 1 quantitative data
	• Interpreting the issues in system 1

Table 23: First Cycle: Diagnosis stage – Data collection tools and Analysis Methods – 1st cycle

4.2.1.1. Process

Building upon the detailed information about how the APS module is managed at BSUKU, the diagnosis stage for the first cycle of the SCOR methodology started from 30th September 2015 and continued until 12th January 2016.

The APS module had been managed through maths workshops and MyMathLab software for three consecutive academic years. Yet, there were increasingly alarming performance results, as discussed in Section 4.1.2.1. As part of the solution, during the meeting of 12th August 2015, the module leader explained her intention to add some tutorial sessions to the structure of the module and to recruit three maths tutors for the academic year 2015-16. Such provision was to support students in their maths skill development and hence to improve their performance. In this vein, since a maths tutor directly helps students and facilitates their learning, the researcher requested to act as a maths tutor and discussed the details of her SCOR methodology as a useful framework that would suitably fit the purpose of the APS module. Upon agreement with the module leader, the researcher was placed in a position where she would have access to both management level information and the data that she could gather from students' level as an internal development facilitator/tutor. Two other maths tutors were also recruited by 1st October 2015.

In the morning meeting of 6th October 2015, the module leader introduced the researcher to the teaching team and tutorial team. The teaching team included two lecturers. The first was an experienced maths teacher and the second was a lecturer recently employed by BSUKU. The tutorial team included the researcher, a PhD student and a new PhD graduate in finance. With 344 students enrolled on the APS module, the module leader discussed her student-streaming plan through five groups for the first semester. Students were allocated to the streams based on their highest past maths qualifications. Table 24 shows the streaming plan.

Stream	No. of Students	Last Maths Qualifications
1	56	A Level A-C
2	40	A Level D, E, IB, and A/S Level
3	85	GCSE A, B
4	82	GCSE B, C
5	81	GCSE C, D, E, F

Table 24 : APS Maths – Student Streaming – First Cycle

Each maths workshop was to be delivered by one of the lecturers and supported by two of the tutors. Five maths teaching workshops per week were planned. The new lecturer was responsible for teaching in stream 1 and stream 2 and the experienced lecturer was to teach in streams 3, 4 and 5. Each of the 105-minute-long workshops should have had three teaching slots (20 minutes each) and three slots of maths problem solving on MyMathLab (15 minutes each). The collective decision made in the meeting was to use tutors in order to facilitate the first semester's maths workshops. The tutorial sessions were left to be planned in the second semester, after the researcher would have examined and analysed the maths learning situation of the APS module. The afternoon meeting of 6th October 2015 was a student induction session designed to introduce them to the APS module, the module leader, the teaching and tutorial teams, as well as the library skills team. Evidently, this session included the immediate stakeholders required for running and supporting the APS module. Starting with the presentation by the module leader, each of the stakeholders, including students, had a chance to discuss their concerns/agenda in the APS module. From this session, the researcher took some observation notes.

In addition, for 10 weeks starting from 19th October to 18th December 2015, each of the tutors, including the researcher, facilitated 19 maths workshops, helping students, via MyMathLab, with maths problem solving. Further, since two tutors facilitated each workshop, the researcher decided to observe those workshops that she was not allocated to facilitate. Through this approach, observation and facilitation notes were gathered from all five streams of students for further assessment.

Further, during the last week of semester 1, i.e. the week commencing 14th December 2015, students had a diagnostic maths test. The researcher received the results of this test as well as students' attendance for semester 1 on 6th January 2016 from the module leader.

4.2.1.2. Finding

For the analysis at the diagnosis stage of the SOCR methodology, viable system diagnosis (Beer, 1985; Espinosa et al., 2013) was adopted to find and illustrate issues in the system. In addition, ethnographic observations of the learning processes in each student stream were performed to describe the processes. A social network analysis was also carried out to visualise connections in system 1. The combination of these three methods provided the results of the diagnosis, which could be used in action planning/design, which will be explained in stage 2 (Section 4.2.2). Referring to Chapter 2 and Chapter 3, this section first identifies the system in focus and its identity, as well as system 1 and meta-systems. Findings are then discussed.

4.2.1.2.1. Viable System Diagnosis: Identifying System in Focus

From the discussions in the afternoon meeting (stakeholders meeting) of 6th October 2015, the identity of the system was clarified for all stakeholders involved. Relating to the findings driven from area of application (Section 4.1.2), this clarification paved the way for the researcher to understand where the focus of this study should be placed. According to the Dean of BSUKU, the APS module is different from the other modules in the business school.

> *"It is a school module. Lots of modules are specific to subject groups but APS is one of those whole school modules. The module leader is in charge and normally that would be under the associate dean" (Dean of BSUKU, 16th June 2016).*

At this stage, most management activities were concentrated on the methods to develop students' skills/capabilities and to improve their performance. Understandably, the new arrangements for this purpose (i.e. adding a tutorial team to the APS-Maths workshops in the first semester of this academic year), would have evolved into a mechanism for the tutor to share more knowledge with the students, once management and students moved on to the second semester. Students had to attend both maths workshops and tutorials. New developments would have emerged when the actions in the current academic year yielded some results and new analysis would have to be carried out at the later stage. Therefore, the system in focus was "the evolving APS module in the business school".

In both the morning and afternoon (induction) meetings on 6th October 2015, it was clear that an appropriate management for APS-Maths activities was required in order to resolve the problems. The module leader presented a statement on the APS module's purpose/identity.

> *"APS is a module to develop academic skills needed for university study through (1) teaching simple quantitative methods (maths), (2) maths support (MyMathLab Pearson and face-to-face), (3) information communication technology (ICT), (4) assignment writing skills, information skills, note taking, learning styles, (5) referencing skills and plagiarism, (6) personal development planning and careers" (Induction Meeting on 6th October 2015).*

Normally, an identity statement is built up with participation from stakeholders and enables them to capture the interplay between the values/meanings that they ascribe to the systems. Using TASCOI (Espejo et al., 1999), Table 25 shows the stakeholders present at the afternoon meeting. Although the module leader and teaching team initially developed the above statement, it was validated as the system's identity by all stakeholders through questions and answers at the afternoon meeting.

	TASCOI – Tool for Clarifying the Identity	
T	Transformation:	Conceptual information turns into knowledge and skills
A	Actors:	Students, Teaching Team, Tutorial Team, Module leader, Library Skills Team (support roles)
S	Supplier:	Teaching Team, Tutorial Team
C	Customer:	Students
O	Owners:	Module leader behalf of the Dean
I	Interveners:	The researcher

Table 25: Adapting TASCOI for Identity Clarification (Source: Espejo et al., 1999)

Both quantitative and qualitative skills were important. Maths skills assessment was through a purely maths exam. Writing skills assessment was through an assignment. According to the module leader there had been no meaningful association between the results of the maths exam and the results of the writing skills assignments in the previous years. The main issue of the APS module was the concerning state of students' maths skills (discussed in Section 4.1.2). Hence, the researcher defined the identity of APS-Maths for a systemic solution in this research as:

> *"APS-Maths is a part of the APS module to develop maths skills needed for university study through teaching simple quantitative methods (maths) and offering insightful and effective ways to provide maths support to students (e.g. face-to-face sessions and MyMathLab)" (Meeting on 6th Oct 2015).*

This statement regarding the system's identity (APS-Maths's identity) is in line with both the identity of APS as a module and APS as a strategy decided by BSUK's management (discussed in Section 4.1.2). Whilst the researcher understands that identity is about what the system is, instead of what it does, the surest way to discover/recognise what the system actually is, can be through expressing what the system does. As Espejo et al. (1999) state, identity makes the field/space in which stakeholders agree to take the challenge of viability more visible. Here the identity statement clarifies said sphere/area as "maths skills development".

4.2.1.2.1.1. Viable System Diagnosis: Identifying System 1

Having clarified the system in focus and the identity of the system, the next step was to identify system 1. A system 1 can be team jobs/tasks that create a product/service directly linked to the purpose of the system. The VSM theory suggests that each system 1 is, by itself, a viable system and should have operational autonomy. With reference to the system's identity for this research, the primary activity of the APS-Maths module was the maths teaching activities. Evidently, streams of maths workshops and maths tutorials represent system 1 of the evolving system (APS-Maths). This clarifies that "only the maths portion of the APS" is considered as the system in focus. Hence, only the evaluation of the maths portion will be used in this research.

Figure 16 illustrates the unfolding complexities. According to Espinosa and Walker (2011), in order to focus on a specific issue, recursive analysis can be used as a powerful tool, identifying the viable systems relative to recursion levels (in effect this is embeddedness at the organisational level). This is referred to as unfolded complexities and helps to work out what is happening at each recursion level. Hence, it models embedded viable systems that are within viable systems and empowers organisations to distinguish the evolving sub-organisational levels, demanding suitable meta-systemic management.

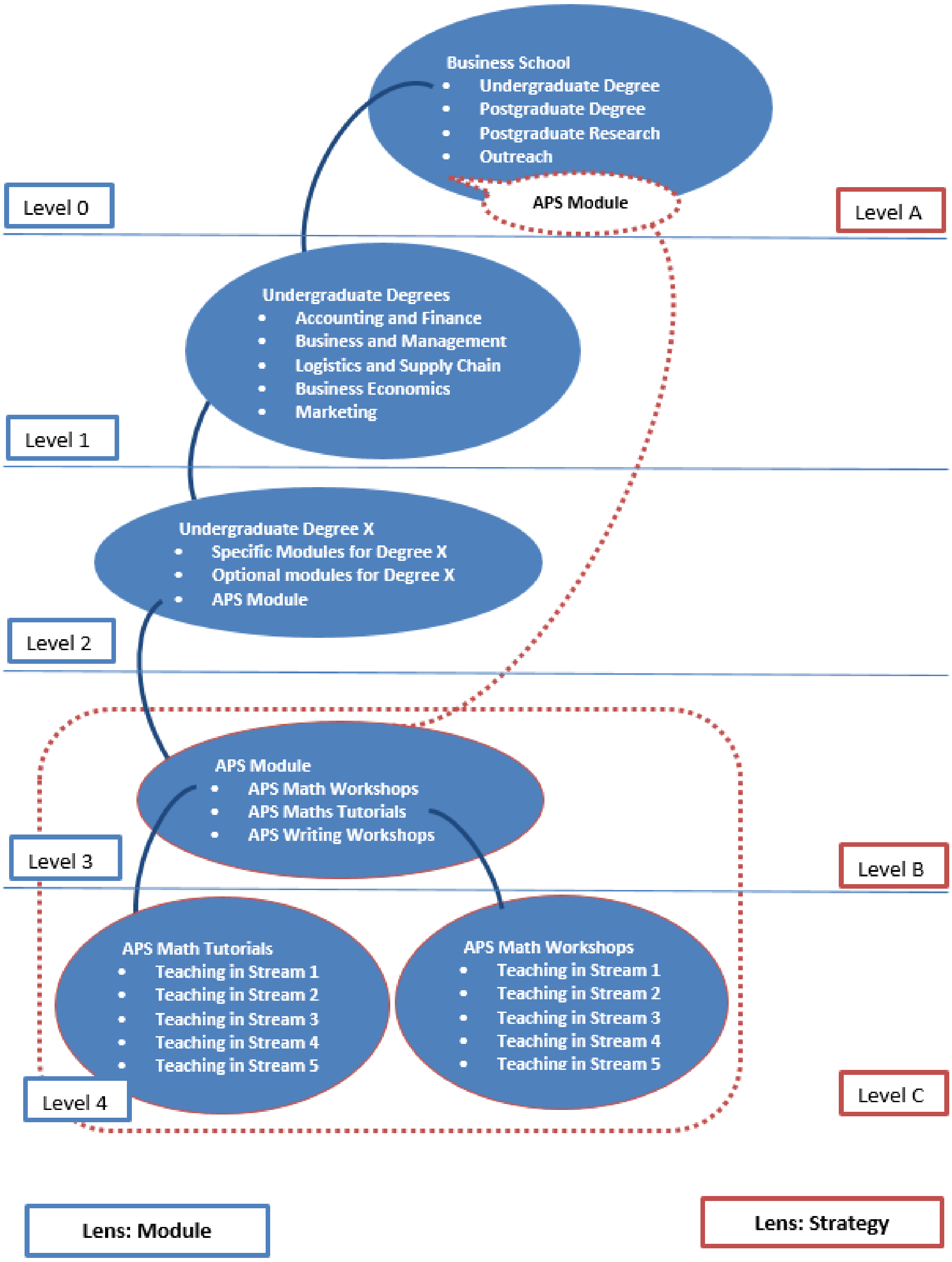


Figure 16: Unfolded Complexities

With reference to unfolded complexities in Figure 16, the researcher understood the interconnectedness of the components in this model through different recursion levels, using two lenses.

The first lens relates to the module perspective. At school level (level 0), primary activities included undergraduate degree, postgraduate degree, research, and outreach programmes management. Each of these programmes had its own core activities. For example, at undergraduate degree level (level 1), the core programmes revolved around management of different types of degrees. Each of these different undergraduate degrees (X) then had specific degree modules, optional modules and the common compulsory modules of APS as the primary activities to be managed (level 2). At level 3, APS's core management activities were the organisation/management of APS-Maths workshops, APS-Maths tutorials and APS writing workshops. At level 4, APS workshops and tutorials' key activities were designed to be "the teaching tasks in the five streams of students".

The second lens refers to APS as a school strategy manifested as a compulsory school module. The researcher suggests that the APS module can also be a primary activity at this level, since it is a strategic solution at the business school (level A). In this perspective, management of the APS module at level B refers to strategic decisions in the management of workshops and tutorials. At the next level (i.e. level C), the strategic perspective on implementation of teaching activities in streams of students can be considered (Figure 16).

4.2.1.2.1.2. Viable System Diagnosis: Identifying Meta-System

After defining system 1, it was important to clarify the meta-system, i.e. systems 2 to 5. The meta-system in fact represents the support and management functions. According to Beer (1979):

> *Meta-system is ''a collection of subsystems that exists to look after the collection of operational elements so that they cohere into that totality which we called the Viable System'' (p.116).*

With due attention paid to the reality of APS being a school module, the researcher has therefore explored and reflected on the structure of the APS module. Different capacities/specific roles were the reference here. The unfolded complexities, as illustrated in Figure 16, as well as analysis of the interviews, were used by the researcher to spot systems 2 to 5.

System 2 in the evolving APS-Maths module was related to the module leaders' meetings and email communications as a way of coordinating and managing the teaching and tutorial teams in terms of regulations and tactical planning. This coordination was related to students streaming and timetabling, handled by the module leader and school timetabling team. The efforts made in this regard were to ensure that no lecturer had more than one workshop to manage at any given time, and no more than one teaching room was allocated to a given workshop. The teaching team and tutorial team then were informed of the streaming plan through an email on 9th October 2015. To allocate the academic staff (lecturers and tutors) in the work schedule, the module leader was flexible enough to let the teaching and tutorial teams choose which workshops they wanted to teach/facilitate with a condition that they cover all of the teaching slots. This was a coordinative/administrative task that the tutorial team, including the researcher, carried out. The discussions on the disputes/conflicts, as well as the use of canvases, e-learning webpages and ICT support, were also considered as a way of ensuring that different teaching/learning activities in system 1 did not step on each other's heels. For instance, when the tutorial team emailed their planned hours to the module leader, she checked the slots and notified the tutorial team of the errors. Further emails were exchanged until the planned hours were fully efficient.

System 3 and system 3* were realised through management activities that were required for smooth and optimised running of the teaching activities in system 1. In effect, the practice of system 3 was related to the executive management of system 1 for which the senior lecturer (the experienced maths teacher) was also involved in, since he was supervising/managing the teaching activities both in the workshops and in the tutorials of system 1. Notably, the senior lecturer's management duties and communications with the junior lecturer and the tutorial team were in the context of participating and contributing to system 3. Hence, system 3 was trying to balance the preferences of elements of system 1 with the contentment of the whole in a distinctive way. This balance refers to (1) resource allocation/bargaining as a two-way communication channel for discussions and negotiations in order to reach agreements, and (2) monitoring and controlling the teaching activities in all five streams of students, both in the workshops and in tutorials, as a one-way communication channel. This is a top-down means for expressing the official requirement and decision made about the choices among alternatives at the higher recursion level. The system 3 was capable of distinguishing and using the two channels. All these were in place as audit tasks designed to maintain the accountability of the teaching team as well as internal homeostasis in management activities. For example, preparing reports/feedback on management of teaching performance is a system 3 role that is performed by the module leader. Other management activities, such as marking exams/tests, as well as provision of feedback during and at the end of the semester, could also be referred to as functions of system 3, which relates to accountability for student results. These includes both formative and summative assessment. The formative assessment was based on the in-process evaluations of learners and their needs. For this purpose, the module leader was asking the teaching team and tutorial team for their observations and feedback on students' comprehension and progress. In addition, another measure to make teaching team accountable was direct feedback about teaching and learning activities from students in system 1 to the module leader in system 3. The summative assessment was related to end of the semester evaluation. The APS module had two elements of qualitative skills (Maths) and qualitative skills (writing). Therefore, each element was to be examined separately. For quantitative skills, an exam (weighing 50%) was designed to assess students' learning, and for evaluation of students' qualitative skills two assignment (total weigh of 50%) were designed. As part of summative assessment, the final mark for the APS module was calculated as the summation of the two proportions. The second marking was a mechanism for monitoring the quality of the marking activities. Hence, the teaching team that was responsible for marking/re-marking exams/tests could also be included as part of the development of system 3. These roles involved producing the final marks, and sending a report to the school exam board, in order for it to be checked. Hence, the exam board had the regulatory activity of system 3. The module performance reports could also inform the future planning in higher recursion level i.e. in system 4. System 3* relates to more sporadic and unplanned audits that monitor accountability interlinks between the primary activities of system 1 and the regulation of system 3. For instance, reviewing the status of the quality and effectiveness of MyMathLab software could answer the question of whether there is adequate infrastructure available for teaching activities to rely upon. This review also looks at whether the queries from system 4 for developing future plans are adequately answered in system 3's management reports. In addition, it randomly investigates whether the mechanism deployed by system 2 are working appropriately. The Deans and module leader checked all of these points.

System 4 was partly related to the managerial capacity to clarify the goals and objectives of the evolving APS-Maths module. The associate dean, the undergraduate degree programme head, and the teaching-learning champion team were part of system 4 (they would also have normally received detailed feedback from the module leader, allowing them to compare strategy vs achievements). The module leader was in charge of guaranteeing achievement of the APS objectives by following the school's teaching policies and strategies. Strategic decisions for future plans were made by system 4. For example, upon receiving feedback from the module leader (with the concerns regarding the maths rate of fail) and after exploring/scanning the strategies adopted by other learning providers in the environment, the provision of tutorial sessions as an addition to the structure of APS-Maths was approved by those responsible in system 4. Another example of the system 4 decision was using the peer-assisted learning method as a solution for students' low maths performance for the year 2015-16. In broader terms, system 4 had several areas in its scope. Focusing on the future, System 4 in BSUKU was contrasting its organisation model with the prospective changes in the environment. This was particularly evident from the new model of structural change that BSUKU was going through. Such changes were also aligned with the change program at higher recursion level in the whole university regarding "Shape and Size". In addition, system four was connected with its resources to adapt the changes. It tried to be effective by managing the information exchange between the scan of the environment (market research) and the way school manage and present itself. This was at two levels. First level was the general management level where the circumstances of projecting the demand for business education services and new development in the field as well as government regulatory matters such as the "Access Scheme" were considered. It is important to note that the access scheme is the UK government national strategy for access and success in order to motivate the nation and in particular, the disadvantaged groups to study at the higher education level (Assests.publishing.services.gov.uk, 2014). The second level was related to effective management of teaching/learning and skills development for every students and especially new entrants. The number of new entrants were increasing because of the government decision to remove the cap on number of students recruited by HEIs (See section 4.1.3) and the access scheme. Considering these two levels of organisational management in the BSUKU, the information exchange between the planning of new scenarios and financial planning in system 4, led to a number of management decisions. An example of such decision in BSUKU was to recruit academic specialist staff who could serve at modules of different levels including the APS-Maths. Another example was related to reducing the administrative tasks of academic staff so they can focus more on educational services such as lecturing and teaching as well as development of new modules and courses. This could ensure the balance between the thresholds of near/mid-term future and the mid-term/long-term future, with respect to the volatility/instability of the environment as well as the threats/pressures and opportunities/prospects in the horizon.

System 5 referred to ground rules, governance and identity of the evolving APS-Maths module. These were discussions in the meetings of the module leader with the teaching/tutorial team in order to understand and follow the ethos and policies of APS management. Through the strategic lens, i.e. school level of recursion, according to the Dean of BSUKU:

> *"I [am] really in a governance role, to make sure it has happened and the right things are being taught" (16th August 2015).*

Hence, the Dean, the ethos and the governing policies of the business school were shaping the ground rules of the way APS-Maths is supposed to be managed. They also monitor whether the balance between the strategic decisions of system 4 and the optimisation/synergy of system 3 is maintained for APS, and for each one of the academic programmes offered by the school. With APS being a school module and as a compulsory part of every undergraduate academic programme at BSUKU, this balance suggested the level and extent of management capacity based on which the meta-system could effectively strategise/handle maths skills developments of the APS module. Consequently, system 5 would be able to make strategic decisions on whether to, for example, increase/decrease student admission numbers and on setting/adjusting the entry requirements.

> *"Also, the other role I suppose, what governs a lot of what you do in APS, is how good students are when they come. A part of my role is setting the level at which we accept students" (Dean of BSUKU, 16th August 2015).*

Present environment referred to current occurring events in the associated environment of system 1. Students in system 1 were directly interacting with their present environments within the course of their learning/understanding the maths/stats topics. In the university environment, the library skills team had a dedicated maths teacher along with other skills teachers so that students across all department could book a session and get help if they required. The interactions were not limited to university environment. For example, 5 of them who had a part time job were engaged with their employers. An employer's requirement that asked these students to do certain calculations could motivate how they would respond to and engage with the school's provision of teaching/learning activities in the maths lessons. One of students who had an internship job interview with Amazon, were asked by Amazon delegates to pass the APS-maths before joining the company so to have the skills of working with numerical data. Understanding what employers do value in terms of the effectiveness of the problem-solving methods, as well as the style of the response to the issues and the easiness of calculations, could add variety to the interactions between a student and an employer. Similar is when students could get to know what employers dislike. In addition, some of students were in communication with their ex-school friends who were in other universities as well as with those of them who embarked on jobs in the market instead of joining higher education institutions. Such communications and later speaking about the information obtained when communicating with the current classmates as well as to lecturer/tutors can be considered as indirect effect of present environment on system 1. These examples provided students with knowledge and understanding of their present environment directly or indirectly. Note: Looking at APS across the whole university (see organisational chart in Figure 17), the role and place of the university as a supporting environment were paramount. On this scale, the tasks/roles were considered as support activities and not central to the identity of APS-Maths. For example, the university invested in a library to act as a facilitative knowledge sharing mechanism that supports students' learning through its various operations, including provision of study skills. In this sense, the study skills section of the library could be considered as a system for which its system 1 was "teaching/tutoring in tailored maths sessions".

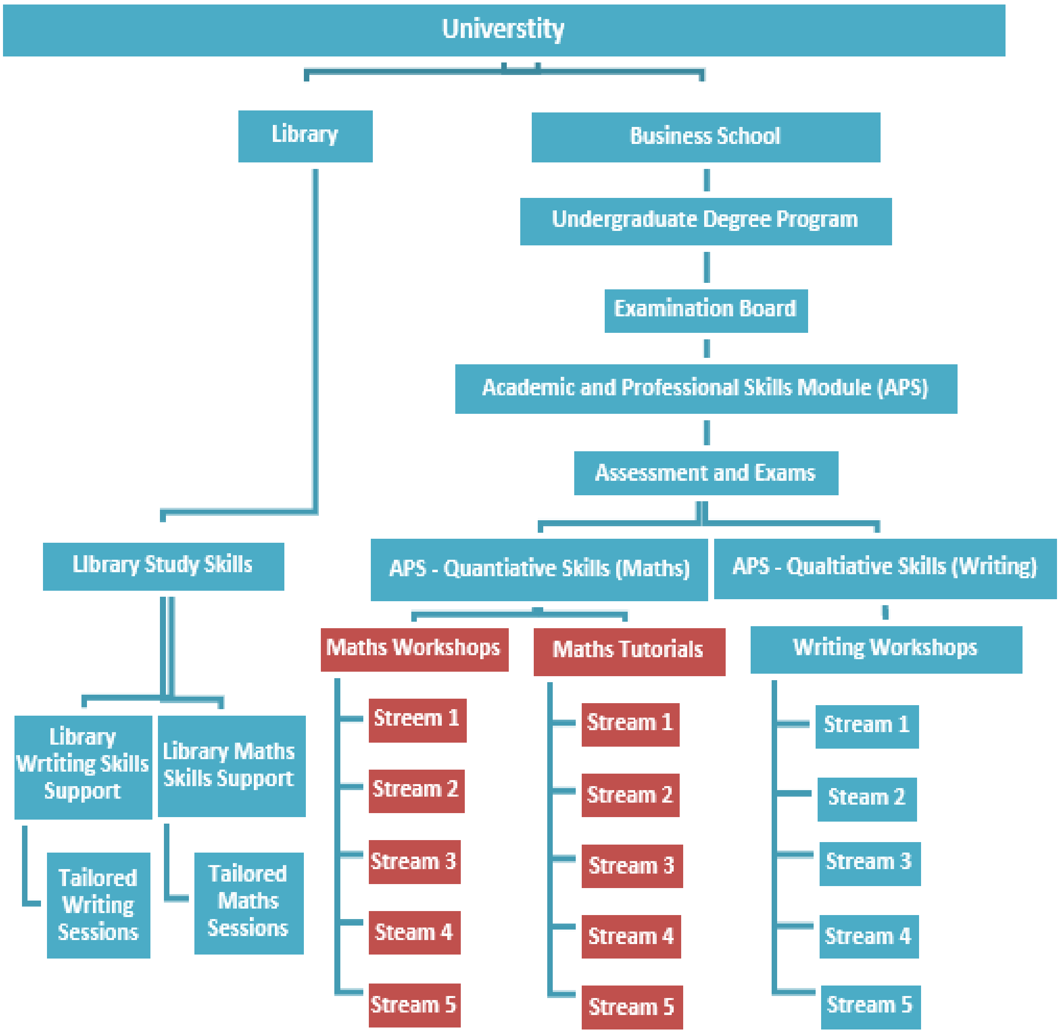


Figure 17: Organisational Chart Relevant to APS

After all, as part of viable system diagnosis, Figure 18 shows the meta-system of the APS module at BSUKU. In turn, it also constitutes the meta-system of APS-Maths to the extent that each of the elements relates to the matters of APS-Maths as part of the APS module. Note: Project manager is the module leader.

To clarify what the meta-system is we need to reflect on Section 2.3.2.1.4. It was discussed there that, according to Beer (p.1085), any viable system has two main abstract components, namely operations and management, which interact with the environment. To go into detail, the operations part relates to primary activities and constitutes system 1. The management part refers to supportive activities and is also called the meta-system. Hence, systems 2, 3, 4 and 5 are indicative of the meta-system. The environment is what surrounds the system as a whole (both system 1 and the meta-system).

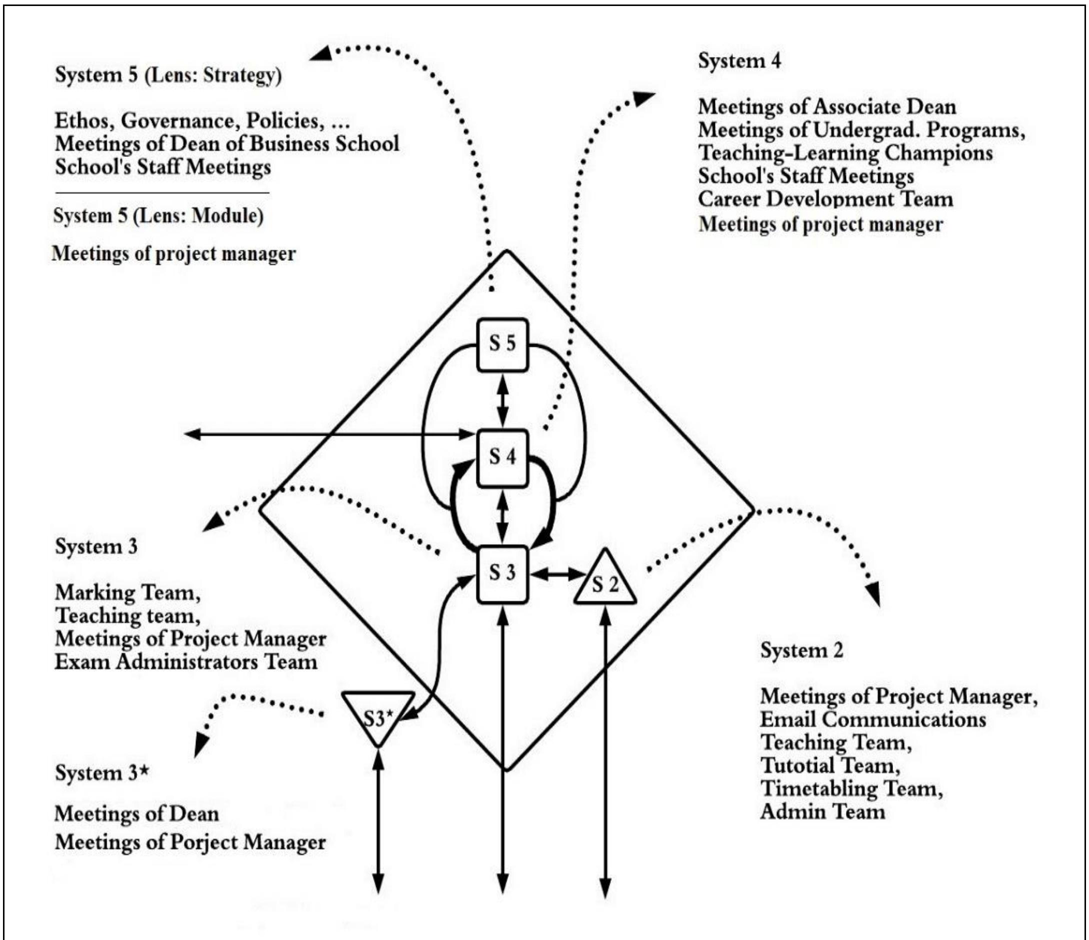


Figure 18: Defining the Meta-System

Several issues have been discovered through viable system diagnoses. The next section will provide the details of the problems.

4.2.1.2.2. *Viable System Diagnosis: Issues*

Closely linked to the meta-system identified above, the researcher adopted Espinosa et al.'s (2013) interpretivist account of Beer's (1985) viable system diagnosis. In order to diagnose and discover the issues in the evolving APS-Maths module as the system in focus, Espinosa and Walker's (2011) meta-questions were also used as a guide (see Table 26). Certain issues emerged from the analysis of the observation/facilitation notes, interviews, and the module leader's feedback meeting with the teaching team and the tutorial team.

Principles	Meta-systemic questions
Co-evolution with the environment	**Enough capability to deal with core issues for viability at each level of organisation** 1. What really matters to each System 1: what do you measure? 2. Are the System 1s operating with real-time information? 3. Are there closed loop Information flows aiming for effective governance? 4. Are the System 1s responding quickly to changes in the environment? 5. Are there effective environments for Decision Making? 6. Are there proper ways to address issues of identity and closure?
Autonomy and cohesion	**Developing meta-systemic management to support autonomous organisations to sustainably self-regulate** 7. Have the operational units enough autonomy to perform effectively? 8. Are there mechanisms to deal with conflicting interests? 9. Are there mechanisms to provide synergy to System 1s? 10. Are there management support systems to deal with critical issues for organisational viability? 11. Are there ways to close the loop on critical issues for organisational viability?
Recursive governance	**Linking local and global governance issues and decisions** 12. Are there enabling conditions for sustainable governance at each level of embedded and embedding organisation?

Table 26: Meta-Questions (Adopted from Espinosa and Walker, 2011, Chapter 3)

System 1 issues:

System 1 (i.e. the five streams of students) was where lecturers could share their maths knowledge through teaching/lecturing in workshops each week. The receivers of maths information were students who had to turn such information into maths knowledge through the mechanism of learning. To examine how effective such learning is, they were expected to answer some maths exercises using MyMathLab in intervals after each 20-minute lecturing slot in the session. Hence, such learning could lead to the development of maths skills and competencies. The core issues observed in system 1 were:

First, the communication was mostly one-way from the lecturer to the students. It was so very rare to observe students asking questions during the lecturing slot. Student-to-student communication was also not encouraged, since the noise could disrupt the learning of other students. The layout of the workshops was not designed for effective communications, collaborative learning or knowledge sharing. All workshops were taught in lecture-type rooms with the lecturer positioned centrally and desktop computers provided for students to individually answer the exercises. Hence, the mechanism and structure to allow knowledge flow among students were missing. In addition, there was no communication between lecturer and students outside the workshop hours.

Second, although two tutors (per workshop) helped and supported students, the time limit for the exercise intervals (three 15-minute slots in the 105-minute workshop) did not allow appropriate knowledge absorptions for all. This was, however, due to too many mathematical concepts that had to be covered in each session. Each student was allocated to attend one weekly maths workshop in the first semester. There were limited chances to attend other streams in a given week to repeat the session, since students would have missed the lectures of other modules.

Third, in the exercise slots tutors and lecturers were frequently asked about the relation between maths contents and business management concepts. It was understood that students consider the contents as not very important for their degree programmes. An example of such a question for a student aiming to pursue an undergraduate degree in human resource management was:

> *"Where do we use quadratic equations in human resource management?" (Facilitation Note, 30th November 2015).*

While it is very difficult for a lecturer or tutor to answer this question spontaneously because the two concepts are indeed unrelated, this incident showed a lack of real-time information in system 1, because the teaching contents were not attuned with skills needed for HRM jobs in the market. The response to these types of questions could not be as fast as required, since a change in workshop contents required specialist knowledge for new material development. Said new material then had to go through a quality approval process at BSUKU. This was indeed a time-consuming and bureaucratic activity and the new material could only be ready for the next year. Hence, the current first-year students could not benefit from the new materials. More importantly, such new contents development could be very complex since the students recruited for different undergraduate degrees were all enrolled on the APS module. Catering for diversified contents to satisfy every perspective was near impossible. Such a question clearly indicated that students are questioning the identity of APS-Maths and implied why teaching activities are not linked to the philosophy of APS, i.e. "for further university study" (see Section 4.2.1.2.1).

Fourth, another perspective was added later when the researcher prepared a list of APS-Maths students who were not attending the workshops. The list was sent to the module leader who then asked one of the student administrators to approach them. An interview with the student administrator revealed that:

> *"Just from what I have heard from students is that the maths for a lot of students is the problem for them, because I think they are just worrying about maths and they come to the business school in the first year. I do not think they realise they are going to be doing a module that has got maths in it. I think this makes them lose hope" (Student Admin Interview, 8th January 2016).*

Fifth, there was a power distance between students and their lecturers:

> *"If power balance is the right word, being in an academic system they are scared sometimes. … I think from the student perspective they are scared to come forward for a number of reasons. They don't want to come. They are sometimes embarrassed. Sometimes they do not want to be seen as having a problem. They want to be strong, and sometimes they feel just so nervous to approach the lecturers" (Student Admin Interview, 8th January 2016).*

System 2 issues:

System 2 related mostly to coordination, stability and dispute resolutions for system 1 activities. The issues in this system referred to the method of coordinating system 1 and tactical planning.

First, the timetabling as part of system 2 did break down all students into five streams based on their highest past maths qualifications. In effect, this means disconnection between those with the highest past maths qualifications (all of whom were in one stream) and students with lower past maths qualifications (all of whom were in the other streams) in their lectures and workshops timetables as per each stream. Despite the advice given to students at the stakeholders meeting of 9th October 2015 (induction) to help each other in learning maths (cognitive capital), the streaming plan (i.e. structural capital) was a barrier for achieving this. Students were very new to BSUKU and many of them did not know anyone (i.e. relational capital). This shows that the coordination for managing the capacity of social capital (structural, relational and cognitive) was ineffective.

Second, nowhere on the meta-system, and most importantly in system 2, was the interplay between the tacit and explicit nature of maths knowledge for students' learning recognised. The method of teaching/knowledge sharing was in conflict with the nature of what was shared. Teaching plans and methods of workshops delivery were designed/approved/monitored throughout the meta-system without due strategic considerations for knowledge sharing/teaching methods relevant to the interplay between the tacit and explicit nature of maths knowledge. In addition, the knowledge sharing was based on the teaching activities of the only two lecturers. The experienced lecturer was to teach in streams 3, 4 and 5 (insufficiently-skilled students), whilst the newly-appointed lecturer was to teach in streams 1 and 2 (highly-skilled students). This strategy might be more useful for teacher management rather than students' learning management, since the ratio of students to lecturer in the streams was very high.

Third, system 2 was also supposed to act as a channel that allows system 3 to monitor and assess information about the activities of system 1. However, it was not noticed by either system 2 (module leader) or system 3 (lecturers/examiners) that the method/tool used in teaching was inconsistent with the method of assessing the outcomes of teaching. For example, lecturers used MyMathLab as an online software tool to engage students in learning during the maths teaching workshops. Yet, the final assessment was set to be an exam on paper. The types of MyMathLab questions (i.e. only multiple choices) were also very different from past exams' questions (i.e. mostly calculations and applications of mathematical procedures).

System 3 and 3* issues:

Since in principle system 3 and 3* should check, assess and audit the procedures of how lecturers teach (given that the primary activity of the system is teaching maths), the last issue mentioned for system 2, i.e. inconsistency between methods of teaching and methods of assessing the learning, is also relevant here. Although academic peer observation is a mechanism to check on lecturers' teaching methods, this did not happen for any of the teaching staff in APS-Maths. Even if such observations would have occurred, implementing the recommendations could take time, since this is related to academic staff development. Hence, the current students could not reap the benefits of improvements in the teaching style of their lecturers.

In addition, approaches should have been established which are more effective in linking the lecturers' performance to the students' learning. This is because of at least three factors. First, learning is an emergent phenomenon and is of a developmental nature. It needs time and practice (experience). Students asked for extra examples and more teaching to absorb the maths knowledge and learn how to solve the questions. It was not possible to satisfy these requests due to the limited teaching time scheduled by the module leader and timetabling. Second, there were strict rules in case of complaints received about exams' marks. In fact, on the examination board, re-marking a student's exam paper is mostly reduced to an administrative task of checking if the marks for each question on the paper add up to the final mark. Third, the feedback on exams or assignments could reach students after they have either passed or failed. If they fail, the feedback (if any is provided) is only useful for the next round of learning of the same module. These issues reveal the importance of creating as many learning feedback loops as possible in students' learning progress, prior to the final exam, in order to link management of teaching with management of learning. Clearly it was not possible for this to happen with current arrangements and resources for the maths workshops. For instance, the limited time in each workshop could only suffice for teaching the concepts with a few exercises. Neither students' learning and reflection time, nor feedback provision, were proportionally budgeted in the workshop time. This therefore hints at the potential for creating a recursion level among the students for the purpose of these crucial activities.

System 4 issues:

System 4 had issues in making strategic future decisions in past years. As mentioned in the issues of system 2, the strategies devised for methods of teaching delivery lacked recognition of how the delivery is relevant to the nature and type of knowledge. However, it appeared that the strategic decisions made for 2015-16 were somehow towards such recognition, because the teaching-learning champion team suggested using peer-assisted learning as a method of teaching and knowledge sharing for students. The teaching-learning champion team comprised academics who scan/research the best practices at other universities and advise internal innovations accordingly. The module leader held a focus group research with the teaching-learning champion teams. Hence, the strategy made in this regard involved learning from similar experiences in other schools. Indeed, this decision did not mean scrapping previous teaching methods, and instead was a good and relevant addition to them, if it could be implemented. This decision, along with another decision about the provision of tutorial sessions for the academic year 2015-16 could have an impact on aligning teaching methods to be more relevant to students' learning assessment. This is because, traditionally, tutorial sessions involve answering certain questions on paper, similar to an exam.

System 5 issues:

From the module perspective, system 5 was following the school policies through the module leader's meetings. Through the strategy lens, system 5 revolved around the ethos and governing policies of BSUKU and monitoring how systems 3 and 4 balance their collaborative undertakings and feedback loops. There had been issues related to APS governance. As the Dean of BSUKU indicates:

> *"I do not think I appreciated sufficiently how important it was. So, I think I delegated the running of it when I first came and it did not go well in a couple of years. I do not think I appreciated how strategically important it was. So,… there were 100 modules in the school to*

look at and [I] overlooked this one though it was so much more important than the other ones" (Dean of BSUKU, 16th June 2016).

With reference to the issues in the evolving APS module of BSUKU (mentioned above), it was evident that the teaching management (meta-system) had undermined the process of learning. In other words, it was more a system for teaching management than a system for management of learning, because a process of learning and skills attainment is developmental and emerging. For such emergence to occur, one potential solution could be to intentionally create the conditions (e.g. offering resources, extra time, etc.) for the emergence of a recursion level among students. This could promote and facilitate collaborative learning/practice and hands-on feedback provision, through peer-assist with a bottom-up approach. In such a potential recursion, students could be empowered to learn how to take control of their own learning (i.e. shaping a meta-system for their own collective learning). Hence, said recursion is more likely to address the power distance between students and tutor/lecturer. In addition, at this presumed recursion level, the students could also form a community/network of learners for collaborative knowledge sharing and learning through experience and practice. The use of experiential learning techniques could therefore directly relate the type of knowledge involved in the maths learning with the type of knowledge sharing/teaching activities.

Following the issues and insights discussed in this section, the researcher next relates to the ethnographic observations of the streams. The observation results and the emerging insights combined contribute to the design and development of a systemic solution aimed at improving students' learning and performance.

4.2.1.2.3. Ethnographic Observations: Processes in the Students' Streams

This section provides a brief qualitative account of the students' learning processes through observations in each stream of the students' network. In order to recognise students' maths learning and skills development processes in system 1, the researcher used observation as an ethnographical technique for each of the streams. The observations started on 19th October 2015, with the start of the maths workshops, and continued until 18th December 2015. These observations therefore revealed important features of the qualitative processes for learning in the students' network. Depending on the stream, students engaged differently in the maths workshops. With the five streams designed to be the venue for teaching activities as well as students' learning and skills development, the observations offered insights for designing more effective and efficient structures, processes and mechanisms for collaborative learning/knowledge sharing and skills development.

Stream 1 (Group A):

Students in this stream were identified as group A, with past maths qualifications of A-level A-C. 56 students were assigned to this group. Through an observation on Friday 4th December 2015 in the maths workshop which ran from 13:15 to 15:00, the researcher observed that:

> *"Students had a strong maths knowledge base as well as the skills to apply the knowledge in the process of solving MyMathLab exercises. They finished the exercises 5 minutes prior to the elapse of the allocated time in each interval (10 min rather than 15 min). Finishing early, they were asking if they could leave early. Problems that needed assistance in exercise intervals were about administrative tasks such as issues in logging in and technical errors on MyMathLab due to simple mistakes caused by misreading the + and – signs (2 students). It was also observed that the use of pen and paper was a common practice (82% of attendants) in answering the exercises, though MyMathLab exercises were to be solved online. Behaviourally, there was no noticeable noise in the workshop. No communications were observed among students at all. They were fully concentrated in both the lecturing slots and the exercise intervals. The only webpages open on their computer screens were the ones for the APS module and MyMathLab. There was no mobile phone on any desk. Mobiles were on silent mode and away from their desks".*

Stream 2 (Group B):

Students in this stream were referred to as group B. 40 students were assigned to this stream. They were students with past maths qualifications of A-level D, E and AS levels. An observation on Monday 30th November 2015 at 12:15 to 14:00 revealed that their maths knowledge base, as well as their skills for answering the exercises, were very good. It was observed that:

> *"They understand most of the concepts. In this session, very few students (4 students) asked for the tutor's approval before applying the formula of the concepts of simultaneous equations as well as quadratic equations. After receiving support from the tutor, two of them mentioned that they required more questions so that they could practise quadratic equations. In addition, 76% of them (22 students out of 28 present) used pen and paper to go through the process of question solving on MyMathLab. Little whispering noises could also be heard as a few were talking to each other when doing the exercises in the corner seats of the workshop, though the class was quiet during lecturing slots. They were presumably listening to the lecturer. There were few mobiles on students' desks. Occasionally students were using them in exercise time".*

Stream 3 (Group C):

This stream related to group C, which 85 students were assigned to. Their past maths qualifications were mostly GCSE A, whilst some had GCSE B. From observation in the workshop of 30th November 2015 at 14:15 to 16:00, it was revealed that their maths knowledge base was good:

> *"About 40 students out of 48 who were present in the session (83%) knew the concepts enough and 34 of them (71%) could successfully apply the concepts in the exercises. With two tutors*

and a lecturer in the class to assist in the exercise intervals, each dealt with 4 to 5 students in the session. The topics of simultaneous equations and quadratic equations were both the subject of the questions being asked. It was evident that students who asked questions required step-by-step guidance throughout the working-out process. They were keen to do more exercises in order to master the topic. Tutors had to develop new questions of a similar type for them to solve on paper there and then rather than on MyMathLab. About 60% of students used pen and paper to solve the questions. There were one or two non-related pages open on the computer screens of five students along with the APS webpage and MyMathLab. They were using mobile phones in the class to send text messages. There was some noise in the exercise slots due to the students talking to each other".

Stream 4 (Group D):

This stream was recognised as group D, comprising 82 students. The past maths qualifications of these students were GCSE B and C. The observation in the workshop of 30th November 2015 at 16:15 to 18:00 exposed that:

"16 out of 44 attendants (36%) struggled with understanding the concepts and 22 students (50%) had difficulty in applying the concepts to the exercises. Students were frequently asking for help. The tutors and the lecturer reported a noticeable lack of confidence and feeling of fear and frustration about the questions among students. It was evident that learning both quadratic equations and simultaneous equations in just one workshop was too difficult and stressful for them. Whilst tutors/lecturer assisted the students concerned, it was not clear whether they grasped the tutors' explanations of the application of the concepts, though they were nodding as if they did. Hence, the lecturer and the tutors suggested that they use the one-to-one tutorial sessions that were on offer from the library maths skills team. The lecturer put the name and email address of the tutor from the library skills team on the board. In addition, about 60% of the students did not use pen and paper. The session was moderately noisy as 7 to 8 students were talking to each other in the back seats. Pages of online games and Facebook were open on 5 computer screens along with the ASP page and MyMathLab. Use of mobile phones for texting was obvious. It appeared that these students were disconnected from the agenda of the session".

Stream 5 (Group E):

This stream was known as group E. 81 students were assigned to this stream and their past maths qualifications were GCSE C, D, E and F. This stream was observed on Monday 23rd November 2015 at 12:15 to 14:00.

"The session had 42 students attending, 50% of whom could understand the maths concepts and were able to apply the concepts to the exercises. The rest lacked confidence to try. The tutors proactively approached 3 students who were not doing anything. Their screens had the APS module page and MyMathLab, yet they were not working on any exercise. They refused any help offered. Only 10 students used pen and paper to answer the exercises. Much talking noise was evident in the teaching slots of the session. At times, they were not listening to the lecture. The noise level was higher in the exercise intervals. 15 students were on online websites, games, and Facebook. Use of mobile phones was a norm and frequent. 4 students left the sessions for different reasons. They came back and left again. 2 students asked if they could change their group".

Although the researcher described one account of observation per stream above, each account provides the norm of patterns observed in each of the 10 workshops per stream respectively. Hence, the reoccurring observations of the learning processes in each stream helped to create a better understanding of the students' learning situations.

Reflecting on the ethnographical observations, the underlying rules of not using mobile phones in the session or using pen and paper were governing the learning processes among students of streams 1 and 2, who had considerably strong prior maths skills. This rule could help them to focus on the exercises at hand. On the other side, the use of mobiles or social media (games, Facebook, etc.) was common within streams 4 and 5, whose members' prior maths skills were very low. Lack of focus was therefore inevitable. It was, however, critical to create and maintain a high level of focus in the learning process. Even if students could not remember much from their prior maths knowledge, with enough focus on the teaching slots in each workshop, they could either learn the concepts and perform their exercises better or could become aware of areas that they did not understand. Therefore, they could plan to improve their understanding in another way, e.g. using library one-to-one maths skills tutorials. This was not happening in streams 4 and 5. In addition, attendance was an issue. It was not compulsory for BSUKU students to attend the sessions. However, the nature of maths knowledge is different from other types. Maths concepts are interlinked and missing even one session would be very risky for students (particularly for those of stream 5). Further, the communication among students could be considered as a double-edged sword. Communication is an empowering mechanism for problem solving. Yet, the danger for stream 5 students in particular was that, in the case of unsupervised/unguided communications, the maths misconceptions/misinformation and misapplications could easily mislead more students and hence worsen the overall performance. Therefore, it was vital to create contacts/links/interconnections among all 5 streams in order to ensure the flow of quality maths knowledge through discussions. If there was a mixture of all maths abilities in each stream, the students' debates and discussions through communications could also challenge the misconceptions. Evidently, the structure of the APS students' network lacked such arrangements. Moreover, lack of confidence in streams 4 and 5 was evident. If there was a skill-mix in all streams, then with the flow of quality maths knowledge, the lack of confidence could be reduced through communications and interactions. The following section provides the visual illustrations of the situation.

4.2.1.2.4. Cluster Assessment of the Streams

This section follows the viable system diagnosis and the fragmentation issues of system 1. The situation in the students' network was visualised using UCINET in its descriptive mode.

4.2.1.2.4.1. Clusters: Visual Illustrations of the Streams

The visual illustration of students' network could provide a better understanding of the structures and the relations within system 1. It could help the researcher to consider the width, depth and extent of the issues along with missing links and opportunities. The researcher used students' streaming data in order to illustrate the clusters. Figure 19 shows how 344 students were initially allocated to the 5 streams and Figure 20 illustrates how students attended in each stream. In order to create the graph in Figure 19, students were coded based on their stream and given a number to separate them from each other. It is important to note that steams 1, 2, 3, 4 and 5 were coded as groups A, B, C, D and E respectively. For example, B32 means the 32nd student in the list of students of stream B. UCINET was then used to created graphs of the coded data. When the graph of clusters was created, the researcher colour-coded the nodes based on the highest past maths qualifications.

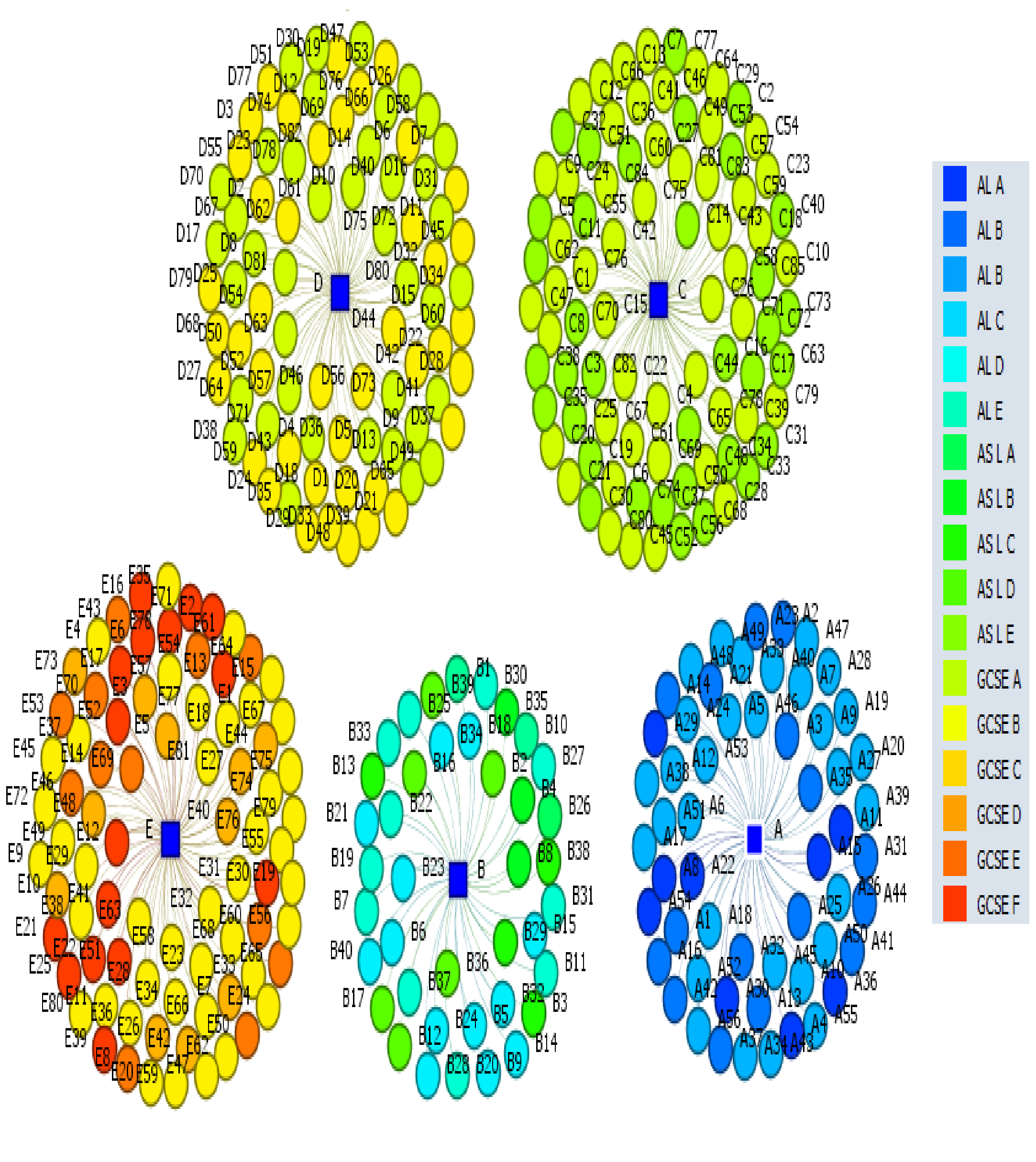


Figure 19: Clusters of First-Year Students – Streaming Based on Prior Qualifications – 1st cycle

In order to create the graph in Figure 20, data was first coded based on the groups and students. The next step was to colour-code the nodes based on the highest past maths qualifications (see the colour codes). Using UCINET, the next criterion was to employ the level of attendance in the 10 scheduled workshops as a measure to show the size of the nodes.

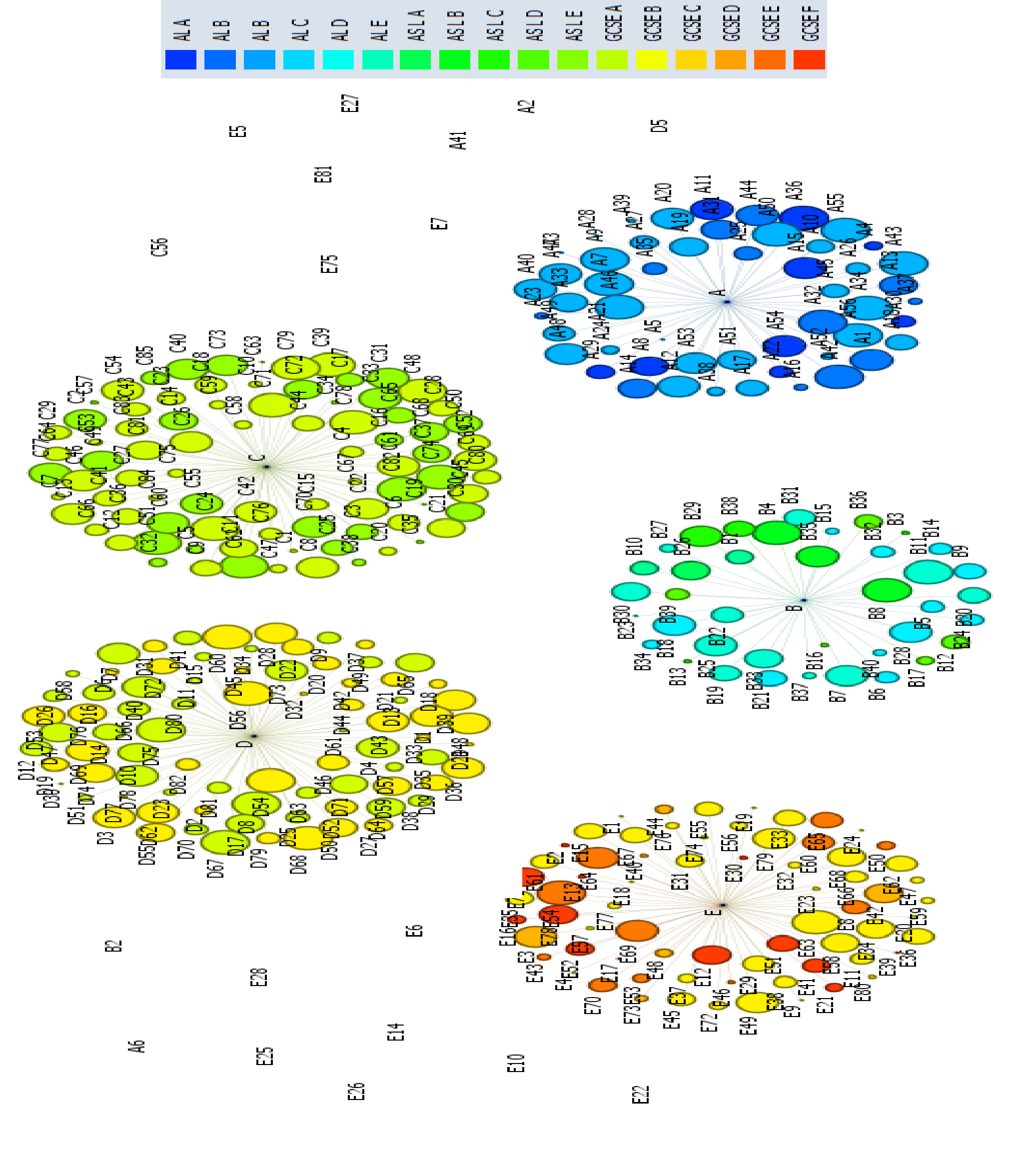


Figure 20: APS-Maths Students' Attendance, First Semester – 1st cycle

From Figure 19, and based on the organisation of the streams, it is evident that there was no link between different streams in the time and space of the lectures/workshops. This meant that the network structure did not provide the opportunities for interactions between highly-skilled and insufficiently-skilled students for collaborative learning. Students with different prior maths level could not interact with each other in the lecture/workshop time, basically because of missing links among the 5 streams of students due to BSUKU's students-streaming strategy. Although there was a chance for students in each stream to get to know who was in their group, this was not very helpful in terms of collaborative learning, practising and skills development. As the observation indicated, streams 1, 2 and 3 did not have many problems in skills development at individual level (due to learners' prior maths knowledge). They therefore did not much feel the need to relate with peers in their group. For streams 4 and 5 the situations were different. Some might have felt the need to relate with others for their maths skills development. Yet, those around them in the stream had the same maths level or slightly better or lower. This echoed the danger of the spread of confusion, mistakes and misconceptions (concluded on in Section 4.2.1.2.3.1). Students in streams 4 and 5 did understand this issue quite well. Whilst it was difficult for them to change their stream, after a month, some of them began to look for students in other streams. Through the dialogue that occurred in the workshops of streams 1 and 2, the researcher traced some of these efforts among students for connecting to peers with better maths knowledge. Three students from stream 1 and two students from stream 2 mentioned that 3 to 5 students from other streams had approached each of them for maths help at the weekends if possible. This suggests that some of the insufficiently-skilled students from streams 3 and 4 intended to increase their learning and development opportunities. On the other side, a measure of access to learning and development opportunities is how students attend their workshops. Whilst lecturers and tutors deliver the learning contents and share the maths knowledge with the students, only well-attending students benefit from their efforts. In particular, at the induction meeting on 6th October 2015, students were presented with the strongly-positive association that exists between attendance and performance. Hence, they knew the significance of attending the maths workshops. The greater the size of the node, the greater the number of workshops the student attended. 18 students (5%) never attended any workshop throughout the whole semester. They are represented by the nodes scattered around the streams.

	Prior Maths Level	No. of Non-Attending Students	Total in the level	% of Non-Attendants (in the same level)	% of Non-Attendants (in their Stream)	% of Non-Attendants (in the whole)
Stream 1	Al B	2	16	13%	4%	0.6%
Stream 2	Al E	2	11	18%	5%	0.6%
Stream 3	GCSE B	8	90	9%	10%	2.2%
Stream 5	GCSE D	1	11	9%	7%	0.3%
	GCSE E	2	6	33%		0.6%
	GCSE F	3	10	30%		0.9%
Total		18				5.3%

Table 27: APS-Maths – Analysis of Non-Attending Students – 1st cycle

Table 27 shows the analysis of non-attendants in more detail. It appears that no one from stream 4 had zero attendance. It also revealed that students with prior maths knowledge of GCSE B level in stream 3 and with GCSE E and GCSE F in stream 5 required attention from the module leader. In addition, since maths relates to an interplay between tacit and explicit types of knowledge and given that the contents of APS-Maths are connected together, catching up would be extremely difficult for students if they do not attend regularly. Hence, the researcher decided to carry out an analysis of those who attended fewer than five workshops in the first semester in order to figure out which streams were in a critical situation. Figure 21 illustrates the situation. This graph was created to show the depth of the issues in visual terms. The number of scattered nodes around the streams was 124. This represents 124 students and means that 36% of the students in APS-Maths attended fewer than five workshops (out of 10 workshops in the first semester). The smaller the number of students who attended the workshops, the smaller the chance they could learn the contents and achieve the maths skills required for assessment of APS-Maths.

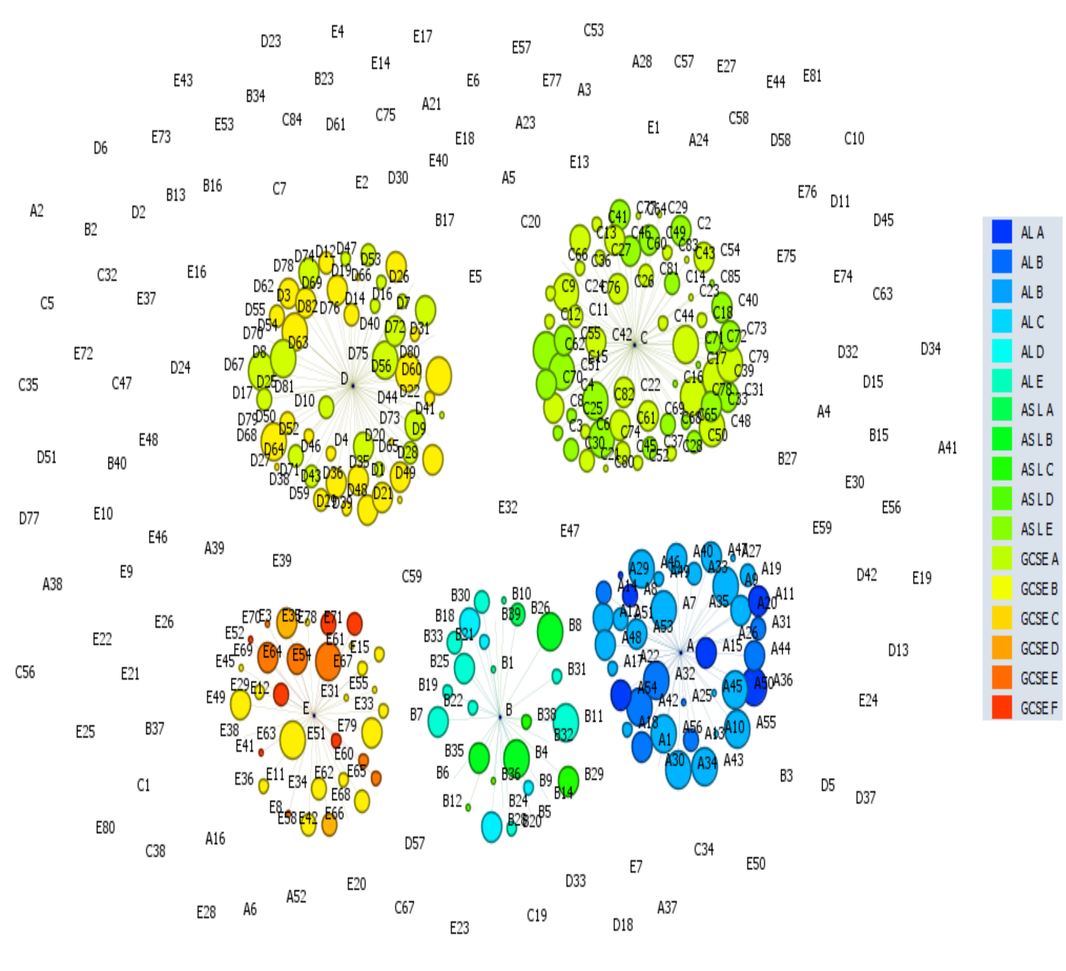


Figure 21: APS-Maths Network – Indicating the Spread of Students Attending Fewer than 5 Workshops – 1st

However, in a sense it was justifiable that students in streams 1 and 2 might wish not to attend the workshops. The maths contents were similar to the level of GCSE and A-level. To those students, repeating the same concepts would be boring and a waste of time. In addition, although enrolment on APS-Maths was necessary for every student, attendance at the workshops was not compulsory. However, students in streams 1 and 2 were not the least attending ones. Table 28 provides a detailed analysis of the scenario.

<table>
<tr><th></th><th>Prior Maths Level</th><th>Attended less than 5 workshops</th><th colspan="2">Total in this level</th><th colspan="2">% attended less than 5 workshops in each level</th><th>% attended less than 5 workshops in the stream</th><th>% attended less than 5 workshops in whole network</th></tr>
<tr><td rowspan="3">Stream 1</td><td>AL A</td><td>1</td><td colspan="2">9</td><td colspan="2">11%</td><td rowspan="3">32%</td><td rowspan="3">5%</td></tr>
<tr><td>AL B</td><td>8</td><td colspan="2">16</td><td colspan="2">50%</td></tr>
<tr><td>AL C</td><td>9</td><td colspan="2">31</td><td colspan="2">29%</td></tr>
<tr><td rowspan="7">Stream 2</td><td>AL D</td><td>3</td><td colspan="2">13</td><td colspan="2">23%</td><td rowspan="7">23%</td><td rowspan="7">3%</td></tr>
<tr><td>AL E</td><td>2</td><td colspan="2">11</td><td colspan="2">18%</td></tr>
<tr><td>ASL A</td><td>0</td><td colspan="2">2</td><td colspan="2">0%</td></tr>
<tr><td>ASL B</td><td>0</td><td colspan="2">1</td><td colspan="2">0%</td></tr>
<tr><td>ASL C</td><td>1</td><td colspan="2">3</td><td colspan="2">33%</td></tr>
<tr><td>ASL D</td><td>1</td><td colspan="2">4</td><td colspan="2">25%</td></tr>
<tr><td>ASL E</td><td>2</td><td colspan="2">6</td><td colspan="2">33%</td></tr>
<tr><td rowspan="2">Stream 3</td><td>GCSE A</td><td>9</td><td colspan="2">35</td><td colspan="2">26%</td><td rowspan="2">36%</td><td rowspan="2">9%</td></tr>
<tr><td>GCSE B</td><td>22</td><td>50</td><td rowspan="2">90</td><td>44%</td><td>26%</td></tr>
<tr><td rowspan="2">Stream 4</td><td>GCSE B</td><td>11</td><td>40</td><td>28%</td><td>14%</td><td rowspan="2">39%</td><td rowspan="2">9%</td></tr>
<tr><td>GCSE C</td><td>21</td><td>42</td><td rowspan="2">84</td><td>50%</td><td>25%</td></tr>
<tr><td rowspan="4">Stream 5</td><td>GCSE C</td><td>13</td><td>42</td><td>31%</td><td>15%</td><td rowspan="4">42%</td><td rowspan="4">10%</td></tr>
<tr><td>GCSE D</td><td>5</td><td colspan="2">11</td><td colspan="2">45%</td></tr>
<tr><td>GCSE E</td><td>6</td><td colspan="2">12</td><td colspan="2">50%</td></tr>
<tr><td>GCSE F</td><td>10</td><td colspan="2">16</td><td colspan="2">63%</td></tr>
</table>

Table 28: APS-Maths – Analysis of Students Attending 4 Workshops or Fewer – 1st cycle

The analysis shown in Table 28 provides detailed information about each of the streams. It is evident that on the scale of all of the APS-Math students, those who have attended fewer than five workshops are mostly in streams 3, 4 and 5. Comparing the streams, it is stream 5 that is most deficiently off, followed by stream 4 and then stream 3. If we focus on prior maths knowledge level, then students with GCSE D, E and F in stream 5 are those who missed at least 5 workshops out of 10. As Table 28 shows, their rates of missed sessions were very high (45%, 50% and 63%, respectively). In addition, 50% of those with A-level B in stream 1 also missed at least 5 sessions. Further, students with GCSE B in stream 3 and with GCSE C in stream 4 missed at least 5 sessions at the rate of 44% and 50%, respectively. From the management perspective, therefore, a challenge was how to deal with the attendance issue, which is an issue of access to learning and development opportunities. Further, since learning and development occurs over time, students' gradual performance assessment as a measure of skills attainment matters. With the formative assessment (a diagnostic test) students could reflect on their learning through the result of the test. Figure 22 illustrates how students in each stream reacted to the formative test.

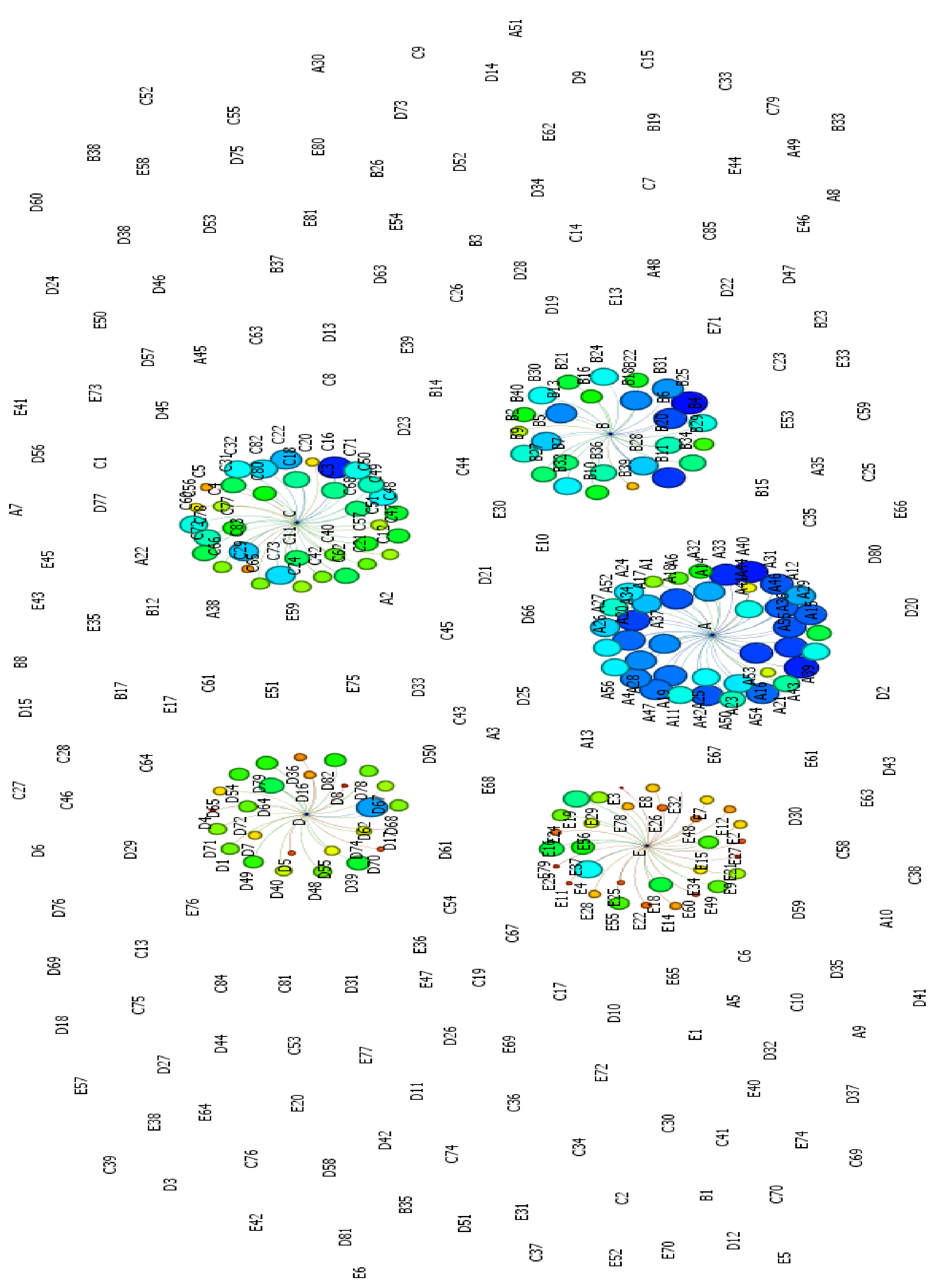


Figure 22: APS-Maths Formative Test, First Semester – 1st cycle

The size and colour of the nodes represent the grades. Dark blue colour shows the highest mark, whilst light green reflects the middle and dark red identifies the lowest grade. Moreover, the greater the size of the node, the higher the mark. The spread of the sizes and colours of the nodes in each stream highlights the level of skills attainment in each. It is observed that streams 4 and 5 were not sufficiently progressing. There were as many as 184 students who did not take the test, which accounts for 53% of them. This is represeneted through the nodes scattered around the streams. Table 29 shows that stream 3 also may have issues since its rate of absentees in the formative test was as high as the rates for streams 4 and 5.

Stream	Range of Marks	% of absentees in the test – Stream level	% of absentees in the test – whole APS level
Stream 1	41 to 87	29%	5%
Stream 2	36 to 89	35%	4%
Stream 3	34 to 86	58%	14%
Stream 4	19 to 80	68%	16%
Stream 5	13 to 73	61%	14%
Total number of absentees: 184			53%

Table 29: Spread of APS-Maths Absentees in the Formative Test – 1st cycle

Understandably, for those who did not try the formative test, feedback to reflect upon could not be provided. In particular, learning from mistakes based on feedback is an effective method for experiential learning and performance improvement. With such level of attendance and performance, as shown in Figure 21 and Figure 22, the goal of APS-Maths in bringing everyone's maths knowledge to a minimum standard could not be achieved. While it was not compulsory for students to attend the maths workshops, there was no alternative mechanism in place to motivate students to attend the workshops. It emerged that students (particularly in streams 4 and 5) did not engage enough with the learning opportunities in the maths workshop process or in any form, through attendance, the formative test or the feedback that could be provided. In addition, the missing links among streams showed the hindrance on the flow of quality maths knowledge among highly-skilled and insufficiently-skilled students. Hence, there was identified no indication to suggest that students' social capital was managed effectively. The cognitive capital amassed in streams 1 and 2 was not utilised through relational capital that could be created between and among streams in order to help in cumulative maths learning issues in streams 4 and 5, and to a lesser extent in stream 3. The effective management of social capital in terms of relational, structural and cognitive capital was therefore forfeited. The circulations of underlying practices that govern the process of maths learning which emerged from observations of streams 1 and 2 (e.g. using pen and paper or not using distracting mediums such as phone or social media) were also obstructed. Clearly, from a management perspective, students' streaming plan of timetabling, as structural capital, was a barrier, since it created instead gaps/distances in the network of 344 APS-Maths students.

4.2.1.2.5. Collective of Identified Issues and Categories

Considering all of the issues revealed through viable system diagnosis, ethnographical observations and clusters of the streams, the researcher logged issues that were identified and categorised them. Table 30 shows these issues and categories.

Co-evolution with the Environment	
Meta-Questions	**Issues**
1. What really matters to each system 1?	• Maths skills development and effective learning through appropriate knowledge absorption are time-consuming. Yet, the intervals of teaching and learning activities/exercises had limited timespan and could not allow for learning to happen effectively. • When doing maths activities, the unguided/unsupervised communications in the knowledge sharing/learning among students of stream 5 had the danger of spreading misinformation and misapplications of maths formula and procedures. This could easily mislead more students and hence worsen the overall learning. • Engagement with knowledge sharing and learning opportunities in the maths workshop was not enough among students of stream 4 and stream 5. • Students did not realise that they have to attend to maths workshops regularly. • Students did not realise they will be doing a module in their first year that has maths in it.
2. Are the system 1s operating with real-time information?	• Teaching in the maths workshop was not reflective of real-time information from the environment (e.g. the maths contents needed to become aligned with skills requirements of business management roles/jobs in the market).
3. Are there closed loop information flows aiming for effective governance?	• Communication in terms of knowledge sharing in the maths workshops was mostly one-way, from lecturer to students. • There was also hindrance on closing the loop in the flow of quality maths knowledge from highly skilled to low-skilled students.
4. Are the system 1s responding quickly to changes in the environment?	• There was a changing environment in job market. This required graduates/students to be equipped with maths and ICT skills. Quick response in terms of change/redevelopment of the maths contents based on new skills requirements for management roles/jobs was not possible due to time-consuming processes of maths content development or technology design etc.

5. Are there effective environments for decision making?	• There was power distance between module leader and lecturer with students. Decisions were made mainly by the module leader. This created an ineffective environment for lecturers to make autonomous decisions for maths teaching and knowledge sharing. Similar is for students to make decisions on their own learning within the maths workshops.
6. Are there proper ways to address issues of identity and closure?	• Maths knowledge sharing did not include sharing information about effective maths learning practices relevant to learners with different skills level. This impacted students' learning, for instance in terms of level of focus on the exercises in the workshops of streams 3, 4, and 5. • There was no effective means to address the problem of operational closure in stream 4 and 5. Those who did not do the test, did not get a feedback to reflect upon. Hence, they missed the opportunity for learning and skill development. • The practice of collaborative knowledge sharing/learning needed an effective workshop layout, yet the layout was not allowing collective learning and effective communications. This impacted knowledge sharing as the core identity of the learning system.
Autonomy and Cohesion	
7. Have the operational units enough autonomy to perform effectively?	• The teaching in math workshops were under bureaucratic rules and regulations, leaving not much room for lecturer's teaching autonomy. This in turn impacted learners' autonomy about taking control of their own learning.
8. Are there mechanisms to deal with conflicting interests?	• The nature of maths knowledge for students' learning was not clearly recognised. Hence, there was conflict/inconsistency between interest of students and lecturer (requiring timely approaches to maths knowledge sharing) and interest of module leader (requiring many maths topics to be covered in each workshop). • There was also conflict between methods/tools of teaching/learning (using MyMathsLab) and methods of assessment (paper-based exam).
9. Are there mechanisms to provide synergy to system 1s?	• There was no mechanism for synergy and collaborations among students with different maths skill levels in workshops. The method of streaming/timetabling caused fragmentations and did not provide the opportunities for interactions between highly skilled and insufficiently skilled students for collaborative learning, though learners were advised in the induction meeting to help each other. Hence, there were missing links and missed opportunities for collaborative learning.

10. Are there management support systems to deal with critical issues for organisational viability?	• There was no indication to suggest that students' social capital was managed effectively. The cognitive capital in stream 1 and 2 was not effectively utilised because there was not much relational capital between and among streams to help each other in increasing maths learning issues. This was more obvious in stream 4, and 5 and to a lesser extent in stream 3. • There was no effective support system to manage/monitor system one's operations. Stream 4 and stream 5 in particular were underperforming in the formative test and exersises. • Attendance was not compulsory hence there were attendance issues in streams 3, 4 and 5.
11. Are there ways to close the loop on issues for organisational viability?	• Managing feedback provision was ineffective. Provision of detailed feedback on students' performance was possible only after the exam. Detailed feedback should have been provided regularly during the course of the module to help in viable exam performance. In such a scenario the loop could be closed by students through reflections on the feedback as well as learning from the mistakes regularly.
Recursive Governance	
12. Are there enabling conditions for sustainable governance at each level of embedded and embedding organisation?	• There was no clear embedded level for students learning within which they could take control of their own learning. • The system for teaching management (embedding) was undermining the system for management of learning (embedded). So, there were not effective governance systems in place between the embedded and embedding organisations.

Table 30: Collective of Issues in APS-Maths

The issues identified in APS-Maths, gathered throughout the diagnosis stage (summarised in Table 30), were used in operation/action planning and design. Given that, according to the module leader, BSUKU was going through a major change orchestrated in the whole university, the researcher had to check the viability of the suggestions with the module leader to ensure they could be practically implemented. The following section relates to the second stage of SCOR methodology of this research, where the action/operation planning and design will be discussed in full detail.

4.2.2. Stage 2: Action/Operation Planning and Design

In the stage of action planning and design, the researcher referred to the collective of issues identified through viable system diagnosis, ethnographic observations and social network analysis. The insights into, and understanding of, the problem, allowed the researcher to design a systemic solution for maths skills development and performance improvement. Table 31 shows the data sources as well as the planning and design methods for this stage. The next section describes the process of action planning and design of the solution in full detail.

First Cycle: Action/Operation Planning and Design Stage	
Data/Information Sources	Performance results of Previous years, Attendance results, the collective of issues and categories identified in the first stage, presented in Table 30.
Planning and Design Methods	**Quantitative analysis of Exam Performance (Beer, 1972)** • Finding the Actuality of system in terms of KPI of Exam Success • Finding the Capability of system in terms of KPI Exam Success • Finding the Potentiality of system in terms of KPI of Exam Success **Considerations for Social Capital Dimensions (Nahapiet and Ghoshal, 1998)** • Relating to cognitive, relational and structural capital through overall students' attendance **Domains of Viable Knowledge (Achterbergh and Vriens, 2002)** • Relating to and interpreting the 31 domains of viable knowledge through creating a method note

Table 31: Methods for Planning and Design in the Action/Operation Planning and Design Stage – 1st cycle

4.2.2.1. Process

Building upon the diagnosis and detailed analysis in the first stage of the SCOR methodology, the researcher designed the systemic solution from 13th to 17th January 2016. However, this process was rooted in several referrals to the literature review prior to this period. The literature review was used as a framework of ideas (i.e. F in F-M-A account of soft systems action research). The skeleton of the operations/actions was then shaped in accordance with the methodology. Since system 4 of the evolving APS-Maths was decided based on the provision of tutorials in the second semester, the first semester's evaluation report and the designed action plan were sent to the module leader and the teaching/tutorial team, on 17th

January 2016. Being a PhD student, the researcher also sent this evaluation and designed action research for academic feedback to her two thesis supervisors. The following section provides the details of how the solution was designed to tackle the issues identified in stage 1, i.e. diagnosis stage in the SCOR methodology.

4.2.2.1.1. Viable System Model: Planning for Better Performance

The researcher at this stage referred to the concept of performance measurement in the viable system model in terms of actuality, capability, and potentiality of the system based on the rates of students' success in the maths exam as a KPI.

Notably, the adoption of this approach is underpinned by the definition of the system in focus. Since the system in focus is "the evolving APS-Maths", the key performance indicator for finding actuality, capability, and potentiality relates to the APS-Maths module level. Hence, the scope of this research does not cover the skills development of each individual student, but rather the collective of them in APS-Maths.

4.2.2.1.1.1. Finding Actuality of the System in Terms of Exam Performance

Actuality in the viable system model is linked to what is being done – about a specific KPI – given the currently-existing resources and constraints. In order to figure out the actuality in terms of exam success, the researcher analysed Table 22 (Section 4.1.2.1) in terms of students' success rates (based on failure rates) in previous years. The actuality of the system in terms of students' success rate stood at 73.85%.

4.2.2.1.1.2. Finding Capability of the System in Terms of Exam Performance

Capability in the viable system model refers to what the system could be doing – about a particular KPI – given the current resources and barriers. In other words, capability relates to the best achievement in productivity so far with current resources and regimes. In this sense, analysis of Table 22 (Section 4.1.2.1) showed that the capability of the system in terms of students' success rate was 83.75%.

4.2.2.1.1.3. Finding Potentiality of the System in Terms of Exam Performance

Potentiality is what the system should be doing – about a particular KPI – through enhancing the resources or removing the barriers. However, this resource improvement or elimination of barriers in the system will have to be realistic. As an improvement in APS-Maths, tutorials were added to the structure of the teaching plans (in comparison to the years before). On this basis, it was expected that students' success rate would increase to 90%. Hence, the system's potentiality was declared to be 90% in students' success rate.

Using the actuality, capability and potentiality of the system, it is thus possible to measure the productivity, latency and performance of the system.

Productivity = Actuality/Capability = 73.85/83.75 = 0.88
Latency = Capability/Potentiality = 83.75/90 = 0.93
Performance = Productivity*Latency = 0.88*0.93 = 0.82 = 82%

Based on viable system measurement, it was therefore expected to observe 82% success in exams for students during the academic year 2015-16.

Having considered the viable system measurement for better performance, the researcher then considered the dimensions of students' social capital in system 1. The following section explores these dimensions.

4.2.2.1.2. Considerations for Managing Dimensions of Social Capital

The researcher briefly considered three dimensions of social capital, namely cognitive capital, relational capital and structural capital. In APS-Maths, students' past maths qualifications represented the cognitive capital. Relational capital revolved around academic relations and communications among students or between students and lecturer. In addition, structural capital in the system was students-streaming plan and timetabling.

At this point, and during the search for an effective way to manage the dimensions of social capital, the researcher reflected on the rate of access to learning/development opportunities in system 1. The objective was to better predict/model and plan for the effective management of social capital as part of the system's capacity. For this purpose, the available attendance results from stage 1 could be used as a proxy to plan for mixing students with different prior knowledge (i.e. mixing different kinds of cognitive capital) by considering how the patterns of their access to learning/development opportunities have emerged (their relational capital), and then creating the conditions that makes learning more likely (structural capital).

From the perspective of access to learning and development, whilst the maths workshop opportunities were available to all students enrolled on APS-Maths at BSUKU, the rate of such access could be obtained through students' attendance. The analysis of attendance provided the researcher with the means to obtain a reliable rate (as a percentage) on how students in different streams were attending/not attending the maths workshops.

Since attendance of at least 5 workshops (out of 10) was important for maths learning and skills development, the acceptably utilised access to learning opportunities in each stream is presented in the last column of Table 32. This table reminded the researcher of the necessity of approaching and motivating the non-attending students as well as those who attended fewer than five workshops.

	Not attended at all	Attended less than 5 workshops	Attended at least 5 workshops
Stream 1	4%	32%	68%
Stream 2	5%	23%	77%
Stream 3	10%	36%	64%
Stream 4	0%	39%	61%
Stream 5	7%	42%	58%

Table 32: Students' Attendance in Each Stream – 1st cycle

Having overlooked the cognitive capital of the highly-skilled students, APS-Maths was mainly resourced by two lecturers and three tutors (cognitive capital of 5 academic staff), to manage the learning and development needs of 344 students. In order to consider students' cognitive capital available in system 1, the researcher referred to students' attendance based on their prior knowledge levels. The reason for this consideration was that the maths contents of the APS were similar to GCSE and A-level maths. Table 33 provides the rate of access to learning and development opportunities for students with different prior maths qualifications. Overall, 64% of students attended at least 5 workshops.

Similarly, if all of students could attend and complete the formative test, then the results of such a test could also be used for recognition of cognitive capital. Yet, since the rate of absence was too high (see Table 28), it was unrealistic to establish the rate of existing cognitive capital based on the formative test. Hence, the researcher found prior maths levels practically more feasible for such recognition.

Following discussion with the lecturers and tutors, GCSE B was chosen as the middle level of the maths knowledge range. Reflecting on Table 33, the researcher then used three measures to establish the ratio of students who are very strong in maths to the rest of the students. First, it was important to consider that holding the highest rank of achievement is recognised as very strong in maths. Second, the researcher conditioned the selection based on rate of attendance to at least five workshops in order to increase the likelihood of the occurrence of an effective knowledge mix for students. The third factor was the number of students at every knowledge level. For example, although for AS level A and AS level B, each had a 100% rate of attendance for at least five workshops, the numbers of students at these levels were 2 and 1 respectively. Similar arguments can be used for AS level C to AS level E.

<table>
<tr><th></th><th>Prior Maths Level</th><th>Attended at least 5 workshops</th><th colspan="2">Total in this level</th><th colspan="2">% attended at least 5 workshops in each level</th><th>% attended at least 5 workshops in the stream</th><th>Proportional % of attending at least 5 workshops among 344 students</th></tr>
<tr><td rowspan="3">Stream 1</td><td>AL A</td><td>8</td><td colspan="2">9</td><td colspan="2">89%</td><td rowspan="3">68%</td><td>2.3%</td></tr>
<tr><td>AL B</td><td>8</td><td colspan="2">16</td><td colspan="2">50%</td><td>2.3%</td></tr>
<tr><td>AL C</td><td>22</td><td colspan="2">31</td><td colspan="2">71%</td><td>6.4%</td></tr>
<tr><td rowspan="7">Stream 2</td><td>AL D</td><td>10</td><td colspan="2">13</td><td colspan="2">77%</td><td rowspan="7">77%</td><td>2.9%</td></tr>
<tr><td>AL E</td><td>9</td><td colspan="2">11</td><td colspan="2">82%</td><td>2.6%</td></tr>
<tr><td>ASL A</td><td>2</td><td colspan="2">2</td><td colspan="2">100%</td><td>0.6%</td></tr>
<tr><td>ASL B</td><td>1</td><td colspan="2">1</td><td colspan="2">100%</td><td>0.3%</td></tr>
<tr><td>ASL C</td><td>2</td><td colspan="2">3</td><td colspan="2">67%</td><td>0.6%</td></tr>
<tr><td>ASL D</td><td>3</td><td colspan="2">4</td><td colspan="2">75%</td><td>0.9%</td></tr>
<tr><td>ASL E</td><td>4</td><td colspan="2">6</td><td colspan="2">67%</td><td>1.2%</td></tr>
<tr><td rowspan="2">Stream 3</td><td>GCSE A</td><td>26</td><td colspan="2">35</td><td colspan="2">74%</td><td rowspan="2">64%</td><td>7.6%</td></tr>
<tr><td>GCSE B</td><td>28</td><td>50</td><td rowspan="2">90</td><td>56%</td><td rowspan="2">63%</td><td rowspan="2">16.6%</td></tr>
<tr><td rowspan="2">Stream 4</td><td>GCSE B</td><td>29</td><td>40</td><td>72%</td><td rowspan="2">61%</td></tr>
<tr><td>GCSE C</td><td>21</td><td>42</td><td rowspan="2">84</td><td>50%</td><td rowspan="2">59%</td><td rowspan="2">14.5%</td></tr>
<tr><td rowspan="4">Stream 5</td><td>GCSE C</td><td>29</td><td>42</td><td>69%</td><td rowspan="4">58%</td></tr>
<tr><td>GCSE D</td><td>6</td><td colspan="2">11</td><td colspan="2">55%</td><td>1.7%</td></tr>
<tr><td>GCSE E</td><td>6</td><td colspan="2">12</td><td colspan="2">50%</td><td>1.7%</td></tr>
<tr><td>GCSE F</td><td>6</td><td colspan="2">16</td><td colspan="2">37%</td><td>1.7%</td></tr>
<tr><td></td><td></td><td>220</td><td colspan="2">344</td><td colspan="2"></td><td></td><td>64%</td></tr>
</table>

Table 33: Available Cognitive Capital (Prior Maths Knowledge) – 1st cycle

In APS-Maths, the highest rank of maths qualification was A levels. The rates of attendance and the numbers of students holding such qualifications were far higher than the rates of attendance and numbers of students with AS levels (see Table 32). Therefore, the researcher considered students with A-level A, B, C, D and E as "very strong" in maths for the purpose of action planning. This class of students is referred to as the part of APS-Maths cognitive capital that could be used as maths helpers for the others in terms of knowledge sharing and collaborative learning through a guided/supervised plan of experiential learning. The researcher then needed to figure out the likelihood of their availability. Based on this classification, the data in Table 33 was analysed further to provide a new perspective. According to such analysis, it was found that 71.3% of very strong students were attending at least 5 sessions (57 out of 80). This rate showed the likelihood of availability of very strong cognitive capital. In addition, APS-Maths was missing 28.7% of its very strong students (for not attending at least half of the workshops). This rate revealed the likelihood of missing opportunities in employing the very strong cognitive capital as helpers. Overall, the 71.3%, however, amounted to 16.5% of the total APS-Maths students (57 out of 344). It was also exposed that the 28.7% (very strong students) who attended less than half of the workshops, actually represented 6.7% of the total APS students (23 out of 344). On the other hand, 61.7% of the not-very-strong students were attending at least 5 workshops (163 out of 264). This rate was related to the likelihood of the availability of the part of cognitive capital that needed further maths skills/capability development. In addition, 38.2% of the not-very-strong students missed half of the maths learning and development opportunities (101 out of 264). This rate referred to the likelihood of missing opportunities to help and develop the not-very-strong cognitive capital further. Out of this group, those in stream 5 were at very high risk of failure, and amounted to 13% (34 out of 264). Overall, the 61.7% who attended at least 5 workshops constituted 47.4% of the total APS-Maths students (163 out of 344) and the 38.2% who missed half of the sessions in fact constituted 29.4% on the scale of total APS-Maths students (101 out of 344). With this information about students' access to learning and development opportunities, it was possible to obtain a new understanding of the available cognitive capital through attendance. Further, attendance is particularly linked to relational capital, representing the patterns of access to learning and development opportunities. With the help of a facilitator/tutor, attendance could provide the opportunities which would make the development of relational capital more likely. This means that students would be able to relate more to each other, to the lecturers, to the tutors, to the learning materials and to the developmental activities. In this sense, availability of students pointed out the capacity for increasing the knowledge sharing and collective learning efforts among students. Derived from the information in Table 32 and Table 33, and despite the student streaming issue, each stream of system 1 could be capable of, and had the capacity for, using its current mix of students' knowledge levels and skills. It is therefore suggested that, in each stream, the lecturer should ask students with better skills (higher levels of cognitive capital) to help others (with lower levels of cognitive capital) in the workshops of the same stream. For example, Table 32 reveals that the ratio of available students with A-level A to C was 1:3 in stream 1, the ratio of AS level D to E in stream 2 was 2:1, and the ratio of available students with GCSE C to F was 5:1 in stream 5. In particular, guided/monitored by lecturers/tutors, stream 5 could benefit more from these efforts within the maths workshops, since the diversity of prior maths knowledge and skills in stream 5 (cognitive capital) was higher (e.g. GCSE C, D, E and F). This cognitive mix, however, should be strictly supervised by lecturers/tutors to avoid the spread of misunderstanding in stream 5, because students with GCSE C are not classified as highly-skilled or very strong in maths. Rather, they can help students with GCSE F with maths questions that are easy to medium (not difficult maths questions or contents). Alternatively (though not recommended), students in stream 5 could have a chance to interact with their stream fellows in order to plan self-organised support meetings, independent of the workshops (e.g. someone with GCSE C meeting and supporting someone with GCSE E). However, without support from maths lecturers/tutors, there was some danger of the flow of misinformation and misguidance. Moreover, the attendance rate of insufficiently-skilled students could also be considered as opportunities for skills development. It was important to consider the percentages and the lists of students who actually attended at least five workshops. This information helped the researcher to relate to the probability of an effective mix of knowledge levels (cognitive capital) being planned for the tutorial sessions in the second semester (structural capital) in a more realistic way; indeed, this reduced the effects of the student-streaming strategy. Reducing this barrier could increase the access to learning and knowledge sharing opportunities at learner-to-learner level (relational capital). Therefore, from the perspective of access to learning and developmental activities, several opportunities came to light. First, non-attending students from all streams could be approached to investigate the reasons for no-attendance and to offer the support available at BSUKU. This could potentially increase the attendance of insufficiently-skilled students and provide them with the learning support needed. Similarly, it could motivate highly-skilled students to attend for their own learning and to support other students.

Operational plan 1:

> In line with facilitating the access to learning opportunities through attendance, the researcher suggested to the module leader that the non-attending students could be contacted and encouraged to attend the sessions. Upon agreement, the researcher prepared a list of students who missed at least 5 sessions in the first semester (both highly-skilled and insufficiently-skilled students) and sent it to the module leader. Since Student Administrations at BSUKU had access to students' comprehensive contact details, the module leader requested one of the student administrators to contact these students individually in order to understand their cases, to offer them the available help and support, and to motivate them to attend their maths workshops and tutorials in the second semester.

Furthermore, for the second semester a different students-streaming method could be applied in order to mix students with different prior maths knowledge (with due consideration to their patterns of attendance). This could fill the disconnections in system 1, and could create and increase the social interactions and engagements among students of streams 1 and 2 with students of streams 3, 4 and 5. It also could familiarise students with the norms and rules of learning processes, all of which was necessary for managing the interplay between tacit and explicit types of knowledge. Therefore, the researcher aimed to mix different kinds of cognitive capital and to create the relevant structure for the emergence of relational capital which is required for collaborative knowledge sharing and learning. Such a cognitive capital mix was expected to create more experiential learning through collaborative practice and reflective understanding. These efforts could then lead to the development of skills and capabilities and improvement of the performance.

Through a learning management lens, since the knowledge is re-created in students' frame of reference, the possible result of lecturers' knowledge sharing is students' learning by means of reflecting on the feedback and understanding (experiential learning). Since this loop is emergent by nature, knowledge management/sharing here was much about creating an environment that facilitates more learning. The greater the number of interactions between very strong and not-very-strong students in the maths workshops/tutorials, the greater the provision of feedback, the higher the number of reflections on the feedback, and the greater the amount of understanding and learning which can occur. Therefore, in order to organise the maths skills-mix, the researcher extracted the ratios of cognitive capital availability, as provided in Table 34.

Base: Attending at least 5 Workshops	Ratio
Very Strong Students (Attending) to Not-Very-Strong Students (Attending)	1:4
Very Strong Students (Attending) to Not-Very-Strong Students (Total of Attending and Not-Attending)	1:5
Very Strong Students (Attending and Not-Attending) to Not-Very-Strong Students (Attending)	1:2
Very Strong Students (Attending and Not-Attending) to Not-Very-Strong Students (Attending and Not-Attending)	1:4

Table 34: Ratios of Cognitive Capital Availability – 1st cycle

It is important to acknowledge that despite the ratios in Table 26, the researcher was aware of the complexities involved in the case of students' attendance. Although this modelling could create a better way to organise and mix students with different maths skills, it was difficult to assert beforehand which sessions out of the 10 workshops they would attend. The worst case, for example, could be that every highly-skilled student chooses to attend just 5 sessions – those 5 sessions that no low-skilled students attend. In this situation, they will never be in the same workshops. However, looking at the data, the proportion of those who attended just 5 sessions in total was 9% (3% for highly-skilled and 6% for lower-skilled students). While the researcher did not have access to the attendance of each student per workshop, this 9% suggests that, among those who attended at least 5 sessions, 91% attended more than 5 sessions and this dramatically increased the likelihood of highly-skilled and low-skilled students being in the same workshops. Hence, the ratio of 1:4 in the first scenario is still reliable.

Operational plan 2:

The researcher prepared four lists for the second semester timetabling. The first list included very strong students who attended at least five workshops. The second list comprised very strong students who attended fewer than five workshops. The third list was for not-very-strong students who attended at least five sessions, and the fourth was for not-very-strong students who attended fewer than five sessions. The ratio and rationale of how to allocate students to the tutorial sessions in such a way to have an equal number of students from each list in each of the workshops and tutorials (and to be repeated the same in each week) was explained to the module leader in an email on 12th January 2016. The timetabling team and module leader were to use these files in order to officiate the process.

It is important to note that the decision to provide tutorials in the second semester could potentially promote two-way communications and reduce the power distance between learners and tutors/lecturers. This is because the nature of a tutorial session is based on questions and answers. In addition, creating a knowledge network in system 1 of APS-Maths, either in the tutorials or separately in such a way that learners could learn how to take control of their own learning and skills development, could compensate for the issues in system 3 and system 3* in terms of providing feedback on time. This could also be a potential recursion in the students' network level and could facilitate collaborative learning and knowledge sharing, which is essentially based on continuous learning feedback loops of experiential learning. Such potential recursion requires guided self-organisation in a friendly environment with a bottom-up approach. In order to provide a relevant action plan to address these matters of system 1, the researcher used Achterbergh and Vriens' (2002) 31 domains of viable knowledge. Such domains of viable knowledge were used to design the tutorials in terms of structures and functions of knowledge management (see Appendix 2: Method Note – 31 domains of viable knowledge).

4.2.2.1.3. Viable System Model: Domains of Viable Knowledge

In order to plan for the required organisational improvements, the primary activity in a maths tutorial session for the system was defined as collaborative peer-assisted experiential learning in teams. Each team was to consist of 1 very strong student and 4 not-very-strong students, since the ratio of very strong to not-very-strong students was 1:4 (see Table 34). It is important to note that the term "very strong student" means a highly-skilled maths student. To shape the structures of the desired knowledge network in the tutorials or in separate sessions and the expected self-organised processes in both primary activities of operation and the meta-system, Achterbergh and Vriens' (2002) 31 domains of viable knowledge were used as a blue print. Such domains (as they were originally designed for) provided the necessary functions required for enhancing knowledge management/sharing. They also particularly offered the means for students to collaboratively play effective roles in their own learning because students were to take the functional roles in their teams and implement the tasks (and they could undertake various tasks/roles along their learning development process). Hence, these domains refer to creating a new organised structure (teams as system 1) using VSM criteria.

This approach is very different from a simple process where teaching maths becomes a task for the very skilled students. What is on offer based on the 31 domains of viable knowledge should not be mistaken/misunderstood as a way of outsourcing the teaching function to the highly-skilled students. In order to justify the benefit of attending the extra maths sessions, the researcher discussed the opportunities for developing the skills of team-working, mentoring, critical thinking, problem solving and knowledge sharing as part of the collective knowledge sharing and collaborative learning. Development of team working skills was based on goal setting, role definition and collaborations towards attainment of the goals. Mentoring skills could be developed through checking teammates' work, providing advice on how to deal with the problem at hand, justifying the relevant techniques and assisting teammates toward solutions for the problem and regulating the processes of learning within the team. Critical thinking skills could be improved through scrutinising performance level against the goals, adjusting the goal, based on team's capabilities or offering new goal relevant to tasks in the team. Problem solving skills could be enhanced via identification of the problems when dealing with maths questions and team's dynamic issues, brainstorming pertinent strategies to tackle the concerning issues and effectively resolving the problems. Knowledge sharing skills could be developed through finding the sources of knowledge, motivating knowledge seekers to ask questions and encouraging each other to share knowledge. This discussion happened in the first week of the extra maths sessions and students were informed that they can add these skills on their CVs and that the researcher would be happy to review their CVs. The researcher also offered to provide mock job interviews and to act as a referee for any of their job applications (see Section 4.2.3.1.3.1 and Section 4.3.3.1). They fully understood and acknowledged the benefits of this approach both verbally and by attending the extra maths sessions. Table 35 presents the interpretation of each viable domain in the system in focus, followed by action plan 3.

Domains of viable knowledge	Interpretation in the context of knowledge sharing/learning
Domain 1: Goals set by, Performance and Modus Operandi of the Primary Activity	The goal of the team is initially set by the researcher but is open to modification based on agreement among students in the teams when they start to participate. Initially, the team' aim is to share knowledge of maths through helping each other in practicing maths questions and to reach the correct answers for the maths exercises. The objective can be set as to increase the number of practice questions solved successfully.
Domain 2: Organisational Goal	The organisational goals are set in line with the APS-Maths identity and purpose specified in section 4.2.1.2.1. The tutorial session as the system in focus is considered as the organisation and its goals is to develop students' maths skills, to level-up knowledge of math in the whole class and to improve students' performance.
Domain 3: Expected performance of the primary activity	Since the primary activity of the system is collaborative peer-assisted learning in teams, it is expected to observe that students can work out the correct answers for the maths exercises and can gradually increase their math's problem-solving skills. This is through help provided to the team members from very strong students who mission to translate the organisational goals into the team goals.
Domain 4: Monitoring and controlling /regulation practices	The control practices are established around peer-to-peer monitoring of the answers that students offer for the maths practice exercises. Here there are two perspectives. First, not-very-strong students can report their struggles to very strong students in the team. Second, very strong students would check and monitor the maths problem solving process and the practice of their teammates. Here the maths knowledge of students in each team is updated when very strong students explain the why and how of reaching to the correct answers. This counts as a collaborative regulation activity in which very strong student supports self-regulation of the team and make sure all understand the tasks and helps in their self-assessment on the process.
Domain 5: Goal and Performance misalignment	The team's goal revolves around working out the correct answers collaboratively, and the performance is observed/monitored/checked by the very strong students in the team. A misalignment could refer to the scenario in which the answers to the maths questions in the team are not the same. This relates to the quality of the individual processes in which the answers to maths questions are obtained. In addition, misalignment can be measured through the number of questions that have been left unanswered at the end of each session against any such goal.
Domain 6: Causes and Consequences of goal and performance misalignment	Very strong students in each team will review how other students have tried to solve the maths questions. They will be able to find the cause of misalignments through discussions. They are also capable of finding the causes of possible problems in the structure of the team. If the team could not find the reasons, tutor will guide/help. The reasons and results are then shared among all team members. Here is where being guided in self-organised teams show its significance.

Domain 7: Actions to counter goal and performance misalignment in primary activities	Either the very strong student will inform any other student in the team of their mistakes or the tutor will find someone in another team to come and investigate what is the mistake. Another student in other teams who has successfully answered the question at hand and reached the right answer can also come to help. That would mean that he/she has the similar skills of very strong student for that particular question now. Therefore, a newly skilled person is borrowed temporarily. If no one appears to have solved the question then the tutors take the lead and guide the whole class explaining step-by-step on how to solve that specific question encouraging students to suggest their methods/views on the way too.
Domain 8: Heuristics to implement counteractions	After finding the reasons of the problem in solving questions, peers from the same team or the selected one from another team will guide the struggling students step-by-step on how to solve the question. This is through providing new or different techniques, processes and explanations. It is possible to brainstorm in the team to select more understandable methods too. Tutor also will come to guide/help if needed, acting similar to a very strong student in the team.
Domain 9: Anti-Oscillatory Measures	Since maths questions have unique and exclusive answers, the oscillation might be based on different ways of solving questions, which can be multiple. Although all methods that reach to the correct solution would be valid and acceptable, yet students will have to be informed that some procedures are time-consuming or more complicated than other methods. Similarly, sometimes easier and more understandable methods would be more beneficial, reducing the risk of simple mistakes or errors when solving maths questions. Form the other side, any student who struggles in a question will have to practice more questions of the same maths concept so s/he would understand the notion and its application. Tutor would simultaneously create more practice questions. Peers in the team will be there to help in this process of solving the exercises. This gradually leads to a belief of ability. Students will rate their abilities at the beginning and end of each session. The tutor can monitor these self-assessment ratings and find measure to manage the issues. Conflicts among team members are also dealt with here.
Domain 10: Interdependencies between primary activities	Any team, who successfully solves a maths question and practice exercises of that type, can reach a level of expertise. Therefore, its team members can be counted as skilled persons on that particular question. They can then help others for the same questions. Borrowing a skilled person (knowledge brokers) either from already strong students in the teams or those who have recently got mastery over a maths topic to guide other teams will make the collaborative knowledge sharing teams interdependent. It is also possible that tutor can temporarily combine two full teams to brainstorm and work together if all members of one team are stressed out due to the hardship of a question. This also relates to interdependencies among teams.

Domain 11: **Actual Oscillations**	While a team's goal is to share knowledge of maths through peer-assist in practicing maths questions and to reach the correct answers for the exercises (experiential learning), however to evaluate the actual fluctuations in a collaborative learning team, it is required to know about the impacts of fluctuations on the team's performance. This can be for instance determined based on how students struggle in solving the questions or through assessing the type of questions that they struggle in or even their self-assessment rates on the feedback forms.
Domain 12: **Actual Performance Loss due to Oscillations**	During the process of collaborative knowledge sharing and learning, the loss of performance can be the number of questions that are left un-attempted in a team due to peer struggle and time limit of each session. The final exam performance also can be indicative in this regard.
Domain 13: **Norms for admitted performance loss due to oscillations**	Very strong students will reflect on their team performance at the end of each session and will provide their knowledge on how they performed and what went wrong in their team. They will provide their feedback to the tutor proposing new ideas for considerations if any. The member' feedback sheet and team feedback sheet will be indicative.
Domain 14: **Gap between norm for admitted and actual performance loss due to Oscillations**	This gap refers to the comparison between the actual and admitted performance loss.
Domain 15: **Causes of the gap between admitted and actual performance loss due to oscillations**	The causes of the gap might be that students do not know a particular maths concept. Sometimes students are not willing to admit and write about their poor maths problem solving performance. Tutor or very strong student in the team might also overlook the performance for a team member.
Domain 16: **Experiences with anti-oscillatory measures**	Tutor asks the team members about how they experienced with practice questions on the way to developing their skills.
Domain 17: **Problems and needs of the management of primary activities**	Students in each team will speak out/report for their learning needs and will discuss the problems encountered in the process of collaborative knowledge sharing and learning. This can be through the feedback form that they will fill in the individual and team feedback forms.
Domain 18: **Proposals for innovation made by intelligence**	Based on feedbacks and ideas reported from the teams, tutor might think of an innovative idea. The remedial innovation is decided here collectively among very strong students, tutor, and module leader with consideration of external environment.
Domain 19: **Desired goal for primary activities based on proposals for innovation**	The very strong students and the tutor will then revise or maintain teams' and class's goals for collaborative knowledge sharing and learning, based on the approved innovative idea. They will also take care of guiding and orienting their teams towards the new goals.

Domain 20: Gap between desired and current goals of primary activity	The tutor in his monitoring capacity as well as very strong students would compare the current and desired goal for team performance.
Domain 21: Required Capacity for reorganisation of primary activities	Assessing the gap between desired and current goal can help in determining the required capacity for reorganisation of maths knowledge sharing and learning in teams of students.
Domain 22: Actual capacity for reorganisation of primary activities	It could be availability of learning space, the number of very strong students as helpers in the teams, and/or the learning material such as books, maths practice questions and exercises.
Domain 23: Gap between required and actual capacity for reorganisation of primary activities	A comparison between required and actual capacity for collaborative knowledge sharing and learning in the teams would determine the gap.
Domain 24: Reviews by control of Proposal for innovation	Very strong students will review the proposed idea for innovation.
Domain 25: Finalized plans for adaptation of organisational goals (A joint product of control and intelligence)	The tutor and very strong students will decide on a plan to adopt the class goals.
Domain 26: Regulatory measures to counter imbalance between control and intelligence	Codes of conduct for lecturers and students would provide guidelines in case of imbalances.
Domain 27: Developments in the relevant environment of the organisation	A scan of external environment can be conducted to foresee if any development can bring new opportunities or threaten the viability of collaborative knowledge sharing and experiential learning in the class.
Domain 28: Norms for balance between control and intelligence	The BSUKU's policy and governance provides the norms to balance between tutor and very strong students, for example, code of conduct for lecturers and students.
Domain 29: Actual imbalance between control and intelligence	Module leader might receive complains from each of tutor and students against each other.
Domain 30: Causes of imbalance between control and intelligence	A detailed feedback from students and tutors to module leader can reveal the causes of imbalance. The module leader also may observe some session and come up with some interpretation on the causes of imbalance.
Domain 31: Experiences with regulatory measures to counter imbalance between control and intelligence	The module leader might ask how application of codes of conduct has helped to counter the imbalance between very strong students and tutor.

Table 35: Interpretation of 31 Domains of Viable Knowledge in the context of Knowledge Sharing and Learning

Using the above domains required for viability of the tutorials, the researcher then designed the session plan accordingly.

Operational plan 3

Each student was supposed to have one maths workshop and one tutorial per week. Structurally, the module leader intended to schedule 5 maths workshops and 10 maths tutorial batches. The researcher planned the first week of tutorial sessions as conversations with participants to reach the conclusive tutorials' goals and purposes, and to come up with the teams' goals, as well as an agreement on/understanding of, the identity. In addition, a discussion was planned around getting to know the method of collaborative knowledge sharing and experiential learning, both in teams and in the class. For this purpose, students were handed a note about the method based on the interpretations of 31 domains of viable knowledge in order to read, reflect and discuss in the class (see Appendix 2). Further, the basics of the viable system model and its five systems were to be discussed briefly to justify the approach (see Appendix 3). The expected benefits for highly-skilled and less-skilled students to participate in the tutorials were also considered through provision of a motivation note (see Appendix 4). For tutorial operations of the second week onwards, the researcher designed a team feedback form and a member feedback form (see Appendix 5 and Appendix 6), as well as a scheduled session plan (see Appendix 7). After discussion with the two lecturers, the relevant materials and maths questions/practice exercises were suggested/prepared for printing on a weekly basis.

The action plans 1, 2 and 3 were discussed in the meeting of 18th January 2016. There was uncertainty regarding whether timetabling would be able to arrange the structural design of the students' network for the second semester both in the workshops and in the tutorials, due to a university-wide major change. Considering the likely timetabling barrier, the researcher suggested an alternative and offered to carry out extra maths sessions in case the timetabling team was not successful in implementing action plan 2. The extra maths sessions could be arranged based on the same principles and the actions could proceed further. The process of operation/action planning and design was finalised on 25th January 2016. From ethical compliance perspectives, BSUKU's procedure was also carried out. The ethical compliance was approved on 11th February 2016 and the research implementation was officially authorised (see Appendix 10). Following the ethical approval and the agreement on action plans between the researcher and the module leader, the next stage of the SOCR methodology of this thesis was action implementation, which will be discussed in the following section.

4.2.3. Stage 3: Implementing the Actions/Operations

In the action/operation implementation stage, the researcher related to the three plans of actions, designed in stage 2.

First Cycle: Action/Operational Implementation Stage	
Operational Plan One	**Contacting not-attending students** Operation by: BSUKU's Students Administrator
Operational Plan Two	**Implementing the researcher's Skills-Mix structure design as a New way of streaming students** Operation by: Timetabling Team

Operational Plan Three	**Creating a knowledge network in tutorials or in extra maths sessions**
	Operation by: The Researcher
	• **Activities of Week 1:**
	  • Teams assembly based on maths knowledge level
	  • Defining Gaols and Identity
	  • Getting to know the method of collaborative knowledge sharing and Introducing the viable system model
	  • Justification on the expected benefits for students with different maths levels
	  • Defining and agreeing on underlying rules for the sessions
	• **Activities of Week 2 and Onwards:**
	  • Teams assembly based on maths knowledge level
	  • Facilitating maths question solving practices in teams through collaborative knowledge sharing, according to 31 domains of viable knowledge (method note)
	  • Gathering the individuals' and teams' feedback forms
	  • Weekly reflection on the feedback forms and monitoring the maths skills development
	  • Weekly Preparation/Printing the learning and practice materials based on the feedback forms

Table 36: Implementing Operational Plans – 1st cycle

4.2.3.1. Process

Building upon the operation/action planning discussed in the second stage of the SCOR methodology, the researcher implemented the operation plans from 8th January to 17th May 2016. It is important to note that the researcher's role in the implementation processes of operational plans 1 and 2 was limited. However, it was the sole operational work of the researcher to implement operational plan 3, which is the core of the systemic solution. The following sections provide the implementation processes in detail.

4.2.3.1.1. Implementing Operational Plan 1

The implementation of operational plan 1 was carried out by BSUKU's student administrator. This was because of BSUKU's internal policies for compliance with the Data Protection Act 1998. According to such policies, accessing the personal contact details of students was only allowed for authorised staff members. Through contacting non-attending students, the aim of this process was to facilitate their access to learning opportunities. Hence, the researcher's involvement was to the extent of preparing a list of students who missed at least 5 sessions. Further, the researcher interviewed BSUKU's students administrator. The module leader also provided a colour-coded list of students based on whether and how they responded to the contacts. From the interview, there emerged a wide range of underlying issues that students were struggling with:

> *"Firstly, not all of them attended the meetings and not all of them got back to me. Some of them would answer the email and kind of give me the reasons why they would not be engaging and I offered email support. Obviously sometimes there are some groups of students that can't engage no matter what you do. So, typically, I would have a conversation on the phone and invite them for a meeting" (Interview with Student Admin, 8th January 2016).*

Or:

> *"So, the students were having personal issues, sometimes financial issues, kind of other life factors, juggling jobs and all sorts of things… Sometimes when students miss a lot of work, they are scared to approach the academics" (Interview with Student Admin, 8th January 2016).*

The remedial actions suggested/taken by BSUKU's students administrator were:

> *"So, I would be then sitting and working with students to figure out what the issues are, talking through practical solutions, what we could do with them, and can you change that hour for students who have a part-time job…. Trying to help them with practical life things that are affecting their academic works, so I worked very closely with support services around the university, wellbeing teams, skills team, language learning centre and I encouraged students to access that kind of support and encouraged them to go and see their module leader, and lecturers" (Interview with Student Admin, 8th January 2016).*

Or:

> *"So, what I would try to advise them is to spend a bit of time looking through the work and identify things that they don't know and need help with and approach the academic that way. Don't just go to the academic and say I have not attended I don't know what I need to do. Come up with focused questions, so you can make the most of your time with the academic" (Interview with Student Admin, 8th January 2016).*

Form the colour-coded list, it was found that upon the communications/discussions with the students, and the remedial actions, three of them decided to withdraw from the undergraduate business management programme. This list was used later after the second semester and the final exam to assess how many of them had actually attended the second semester's workshops and tutorials and how many of them had passed the final exam. This information will be provided at the assessment and evaluation stage of the SCOR methodology.

4.2.3.1.2. Implementing Operational Plan 2

BSUKU's timetabling team was responsible for implementing operational plan 2. The aim was to restructure the skills-mix of students in the maths workshops and tutorials as a new students-streaming strategy for the second semester. The researcher's involvement was up to the stage of designing the skills-mix. Students were divided into four lists based on both their maths skills and attendance, as mentioned in Section 4.2.2.1.1.3. Providing the four lists and ratio of skills-mix, the researcher expected that the timetabling team would be able to create and maintain this ratio in all of the maths workshops and tutorials. The module leader was in direct contact with the timetabling team. Despite every effort by the timetabling team and module leader, it was not possible to restructure the skills-mix. As revealed from the interview with the Dean of BSUKU, he also got involved in the case of APS-Maths scheduling.

> *"So you need a support in timetabling and organising. Timetabling for APS was a nightmare last year. I had to make a formal complaint to timetabling about this" (Dean of BSUKU, 16th June 2016).*

Or:

> *"We are reshaping the university at the moment and there is going to be a person in each school who does nothing but look after timetabling, scheduling and that sort of thing. That sort of person would need to take this course of work" (Dean of BSUKU, 16th June 2016).*

Reaching this point meant that implementing operational plan 2 was not possible. APS-Maths for the second semester therefore consisted of 5 streams of workshops and 10 streams of tutorials repeated for 10 consecutive weeks, with the same cognitive mix as the first semester. At this stage, with no chance to create the underlying skills-mix structures, the researcher decided to proceed with the agreed alternative, i.e. provision of extra maths sessions in order to operationalise the systemic solution, alongside maths workshops and tutorials.

4.2.3.1.3. Implementing Operational Plan 3

On 20th January 2016, the module leader requested that the tutorial team to select the maths workshops and tutorial sessions they want to deliver. However, contrary to the first semester, this was to allocate only one tutor per workshop for learning facilitation (along with the main lecturer of each workshop). Tutorials were separate sessions; one tutor could lead each. The tutorial team responded to the module leader's request on 25th January 2016 accordingly. Tutorials changed to become of a traditional type (i.e. the solving of certain pre-determined maths questions by a tutor in the session). The maths workshops started from 1st February and maths tutorials began on 8th February 2016 and continued every other week. Hence, either a workshop or a tutorial was there for students to attend each week.

In order to implement the third action plan (creating a knowledge network and/or potentially a new recursion level), the researcher scheduled the extra maths sessions (see Appendix 7). The schedule was set to commence after the normal teaching hours at BSUKU in order to avoid conflicts with the timetables of other modules and lessons.

The researcher printed the schedule for the extra maths sessions as well as a note on their expected benefits and distributed said schedule among students in the workshops and tutorials. Since the researcher was also acting as a tutor in the streams of workshops and tutorials, it was possible to connect to both highly-skilled and low-skilled students and invite them to attend the extra maths sessions. This could make students aware of the collaborative knowledge sharing and experiential learning in such sessions. The schedule was also announced on e-bridge (the online software for module management and learning).

With the four lists of students as per operational plan 2, designed by the researcher, it was possible to create the teams' skills-mix in each extra maths session, facilitating collaborative knowledge sharing and experiential learning. Therefore, the details of operational plan 3 were used to be implemented in the extra maths sessions.

4.2.3.1.3.1. Implementing the First Week's Activities

Upon announcement, initially 40 students with different skills-mixes attended the 3 sessions in the first week of extra maths sessions (19th - 26th February 2016). Since these sessions were part of the systemic research for this thesis, participants signed the consent forms (see Appendix 11 and Appendix 12). The sitting layout of the class was turned to banquet style in order to accommodate teamwork. In each session, the researcher asked one of the highly-skilled students present in the session to sit with a group of four low-skilled students. The four lists were handy here when they signed in.

The researcher introduced herself as a researcher (PhD student) and a systems thinker with a first class degree in mathematics. This was followed by discussion of a brief account of relevant issues diagnosed in the APS-Maths module. Since the researcher was extensively involved in the maths workshop facilitation in the first semester, students did consider her as an internal expert and a facilitator for maths skills development rather than an external expert. The relationships built up beforehand in the first semester substantially reduced the expected anxiety and concerns over the types of relations and power balance between students and the researcher. However, the researcher sensed anxiety among students regarding their own level of maths knowledge. In the discussion, one of the students mentioned the following and a few others nodded as if agreeing with the statement:

> *"I think my problem is that maths is not for me. I do not understand it. My brain does not get it" (Student Comment, session 1).*

Another student stated:

> *"I got an A-level D in maths but sometimes I make very silly mistakes when I solve maths questions. How can I resolve this?" (Student Comment, session 1).*

The researcher then invited every team to self-organise together a discussion and present a goal for their teams with due consideration paid to the needs of those who felt anxious about their maths skills. In addition, a sample of maths questions was handed to each team in order for them to envisage an image about the skills level they needed to reach in order to succeed in the final assessment. Picture 1 reveals students' reflections on the sample of maths questions as well as discussions on the team goal. Picture 2 reflects a team discussion in order to define a collective goal for their team. The researcher here advises students to work as a team.

Picture 1: A Team Reflection on the Sample

Picture 2: A Team Discussion to Define a Team Goal

After this team activity, the researcher facilitated a discussion in order to reach an agreement for a class goal and an identity of the extra maths sessions in line with identifying the evolving APS-Maths at the higher recursion level. Students began to discuss and link all team goals and ultimately agreed on a collective class goal, relevant to the identity of the APS-Maths module. Teams' goal (representing system 1's objectives) was:

> *"To answer all questions by helping each other in the teams".*

The class goal and identity for these sessions (referring to system 5's function) was:

> *"To create a maths knowledge network for developing maths skills and getting passed in the exam".*

The next step was to persuade students to use the method of achieving the goal and identity. The researcher handed the method note of knowledge sharing and collaborative experiential learning (see Appendix 2) to each of the students so that they could read it, reflect, discuss and scrutinise. The conversation was followed by a brief introduction to the basics of the viable system model and its five systems (see Appendix 3). The researcher explained how the viable system model and the method note are related. Members of teams were willing to learn how to take control of their own experiential learning through the method provided. They then began to understand the expected benefits of the knowledge sharing method for all team members with different skill levels. Evidently, involvement in the clarifications in a simple and comprehendible way could encourage and motivate students to engage in their skills development and performance improvement.

At this point in the first week, the researcher referred to the relevant issues of the first semester, suggesting that some governing rules could be decided on for the sessions; indeed, she gave a specific example of "not to use social media in the sessions". Students were asked to discuss, in their team, the conditions under which they can learn maths better. The researcher intended not to force change but to facilitate a dialogue on the status quo, asking if students were interested in a new status quo. Evidently, the skills-mix of the team was helpful here since different behaviours and manners were exposed to both highly-skilled (very strong in maths) and low-skilled (not-very-strong in maths) students. The dialogue led to an agreement:

- *To maintain a friendly learning-focused environment*
- *To undertake teamwork in order to solve maths questions and to practise*
- *To cover lots of concepts in a short period of time*
- *To allow snacks and soft drinks*
- *To receive phone calls only if it is an emergency*
- *To respect the code of conduct of BSUKU*

These rules clearly represent the ethos, code of conduct, and governance of the system, indicating system 5 in the viable system model.

4.2.3.1.3.2. Implementing the Activities of the Second Week and onwards

The systemic solution of collaborative maths knowledge sharing activities was implemented from 8th March to 17th May 2016, and the number of participating students reached 52. Despite the extra maths schedule, which was planned for 10 sessions, the number of collaborative sessions expanded beyond the plan. There occurred 16 sessions based on the students' feedback forms (19 sessions in total including the first week's sessions). However, the students knew that 17th May was the deadline, since the final assessment was scheduled by BSUKU on 18th May 2016. Similar to the first week, the 1:4 ratio of very strong students to not-very-strong students was the basis for team assembly in each session. Having understood the method of collaborative knowledge sharing and experiential learning in teams during the first week, students embarked on solving maths questions and practising together in teams, every session afterwards. However, this was not the only agenda for students. The researcher facilitated 10 minutes at the end of each session for students to reflect on their practice and brainstorm/discuss/approve ideas for improvements and progress (see Table 37).

Session Plan Blueprint	
12:00 – 12:05	Teams assembly
12:05 – 12:15	Reminders to the team goal, class goal, rules, regulations and identity Briefing on feedback from last session Distribution of the maths questions and exercises
12:15 – 12:25	Individual students answer 4 questions
12:25 – 12:40	Peer check, recognitions of errors, team discussions (with reference to the note on the method)
12:40 – 13:00	Individual students answer and questions
13:00 – 13:20	Peer check, recognitions of errors, team discussions (with reference to the note on the method)
13:20 – 13:40	Tutor check and explanations/discussions (with reference to the note on the method)
13:40 – 13:50	Feedback Discussions, Strategy development
13:50 – 13:55	Collecting feedback forms, Final remarks

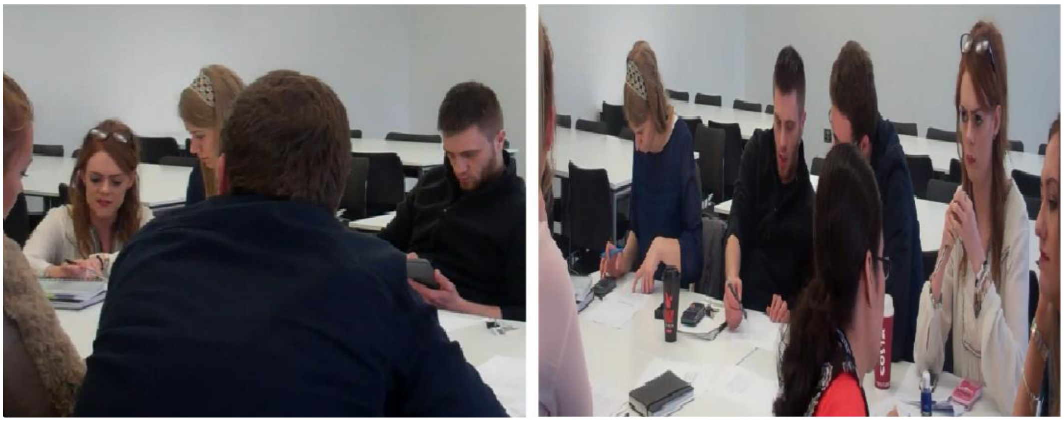
Table 37: Session Plan for Systemic Solution on Maths Skills Development

Pictures 3 and 4 refer to processes of experiential learning and collaborative knowledge sharing in teams and in the class.

Picture 3: Teams' Processes of Experiential Learning – 1st cycle

Picture 4: Teams' Processes of Experiential Learning – 1st cycle

Whenever all of the teams struggled in understanding the question or a concept, the researcher explained the question/concept to all on the board. Having reached an understanding of the questions, students then attempted to answer said questions. Since teams were sitting close to each other, it was therefore possible for them to seek help from the other teams during the sessions. In addition, picture 5 shows two students from a team who successfully answered the questions and agreed to stay longer to help the second team. These highly-skilled students in fact became the knowledge brokers.



Picture 5: Knowledge Brokering in Two Teams – 1st cycle

Finally, as part of the feedback provision in each session, students were asked to rate their ability and confidence in the practice of solving maths questions on the feedback forms at the beginning and at the end of each session. The feedback forms also captured information on how students shaped the way they analysed their teams and their class system. The following sections provide three main types of internal feedback loops.

4.2.3.1.3.2.1. First Type of Feedback Loop: More Experiential Learning

Students reflected on their skills development and recognised which maths areas/concepts still need more questions for practice in each session. This indicated the importance of the experiential learning cycle and choosing relevant strategies through team reflections. In this case, the strategy was to continue the experiential cycle until everyone in the team could feel confident in solving the maths questions. The researcher was selecting the practice questions dynamically to be printed for the next session. This was contributing to the alignment of practice materials with the strategy that students found viable for their skills development and performance improvement in their teams and in the class. This could be interpreted as system 3's effort in monitoring and regulating the processes in system 1 as well as the tactical planning of system 2.

4.2.3.1.3.2.2. Second Type of Feedback Loop: Access to an Online Platform

Since a few of the students forgot the time schedule of the sessions, they asked if an online platform could be developed so that they could be notified on the day of the maths sessions through their mobile phones. Creating a Facebook group for this purpose was suggested, so that everyone could join. This could reduce the lack of focus observed in the first semester's workshops (due to the social entertainment on Facebook) by redirecting students' attentions and engaging them with their learning agenda. With the practice sessions scheduled in such a group, all members could be notified an hour before the session and could have a chance to attend. Students debated this suggestion. They argued that it is also possible to solve some of the questions by taking a picture of any question they feel is difficult and posting it on that group to get help from anyone who can solve it. This could be through posting a picture of the solution in the comment section of said question. They asked the researcher to create the group, advertise the maths sessions there and also monitor/check the answers to the questions. The researcher created this Facebook group and named it "APS Maths Knowledge Network" to resonate with what they do. The description of the group was "Here is the APS Maths Knowledge Network designed for effective, efficient and modern way of learning and practising Maths in a happy and collaborative environment. Please feel free to add your APS classmates".

4.2.3.1.3.2.3. Third Type of Feedback Loop: Managing Teams' Complexities

An important capture on the feedback forms related to the two sessions in which not enough highly-skilled students attended to help low-skilled students (with the ratio of 1:4). Those highly-skilled students who attended were frustrated with regulating the balance between responding to questions/checking the answers/discussing the methods for team members and their own practice/learning. The coordination task was an overwhelming issue here and they rated their personal skills and confidence low. With the relations built up among the students in the class, they then started to strategise on how to resolve this issue. They found that they should become more active in attracting highly-skilled students to attend the sessions. They then decided to find more highly-skilled students in their timetabled tutorials and workshops and to add them to their Facebook group so that they would receive the notifications and attend the practice sessions. The member area of this Facebook group showed the surge of new students being added/asking to join after that discussion. Students joined the group in the practice sessions afterwards. The figure eventually reached 108 students. This case represented the awareness of the link between system 1 and the local environmental conditions. While the Facebook group was mainly created to act as system 2, it also had the potential to serve as a complete online system on its own. It is important to note that the researcher did not use the data from this Facebook group to create the SNA-graphs. This was because members could delete their posts and comments. Therefore, using online communication data in an accurate way was not possible.

4.2.3.1.3.3. System's Evolutions: Emerging Phenomenon

As the number of extra maths sessions increased, students reached a higher level of confidence and exhibited an improved ability to solve maths questions. This was evaluated by self-ratings of students' perceptions of their skills as well as confidence at the beginning and at the end of each session. The time series developed by this data showed such improvement in maths problem solving (see assessment stage of SCOR methodology). They could take control of their process of experiential learning, since they were strategising for their maths skills development in a friendly environment with no hierarchal structure and the researcher guided/facilitated the self-organisation of activities. It appeared that two specific types of event started to emerge.

4.2.3.1.3.3.1. Emerging Event: Development of Knowledge Leaders

It was in session 12 that one of the highly-skilled students (A56) asked if she could be given the opportunity to lead the maths session and to manage the collaborative learning in the teams and in the class. She also repeated her request in session 14. During session 14, the researcher discussed this possibility with her and it was agreed that, at the end of the session, they would ask the students if they wished for her to take the lead in a class. Since students found her very helpful in monitoring/checking/discovering/correcting their mistakes in the previous sessions, the debate resulted in a consensus in the class which was in favour of this decision. At the end of session 14, she stayed longer to have a look at the feedback forms in order to foresee the type of maths questions required. She and the researcher mutually selected the questions for session 15. It was agreed that the researcher would attend the session only as an observer, to give her the opportunity to experience full class leadership. The researcher then booked the space for session 15, announced it on the Facebook page, and printed the maths questions using staff facilities at BSUKU. The student led session 15 effectively. It was observed that she could manage the team processes and facilitate the session well. She asked the teams to fill in the feedback forms and they debated the issues, as well as the possible solutions to said issues. They then strategised on how they wanted the next session to be.

Picture 6: The Team Processes in the Session Led by One of the Students (A56) – 1st cycle

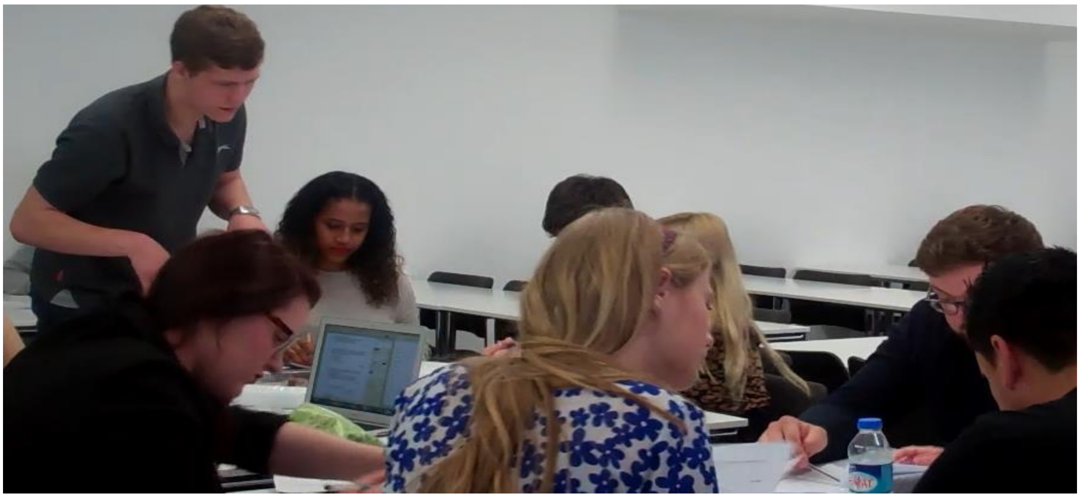
Picture 6 shows that the same pattern of activities emerged in the session led by this student. Said event presented the evidence to show that she is what the researcher tends to call a ‘knowledge leader’. She emerged from being a knowledge broker between teams to a knowledge leader of the session where she ventured to lead/guide the whole class in their collaborative knowledge sharing and teams’ experiential learning. This newly-developed knowledge leader discussed with the researcher her intention to continue in the same way during session 16, which she in fact did.

Further, as part of their strategy development and considering that their exam was approaching, students decided to reflect and revise on whatever they had practised from session 3 to session 17. They wanted to bring in questions that they had doubts about as the agenda for session 18. Hence, they asked for a day-long maths session. The researcher carried out this session. The last session of the systemic solution (session 19) was a further revision session in the first cycle.

4.2.3.1.3.3.2. Emerging Event: Ability of the System for Self-Reproduction

From session 14 onwards, students started to ask if the researcher could facilitate the same types of sessions for their accounting and finance module. It was not possible for the researcher to take on this request. However, one of the students (C39) suggested that, if the researcher were to book the space, he would organise and facilitate the experiential learning sessions for the accounting and finance module. It appeared that he had strong accounting skills. Making such an arrangement led to actual implementation of the same method, this time for another module. The students used the method note given to them in the APS-Maths extra sessions as the blueprint.

Picture 7 shows that he is monitoring the activities. The researcher attended this session and observed the experiential learning going forward, similar to what happened in the APS-Maths practice sessions. He also used the Facebook group to announce the accounting practice sessions. Here, through participation, the students produced observations and practical evidence which showed that the system for APS-Maths practice sessions is serving its purpose and identity. This evidence provided enough motivation for them to think of the same method, reproducing a similar system in order to serve the purpose of skills development in performance improvement in the accounting/finance module.



Picture 7: Teams' Processes in the Accounting and Finance Session, Organised/Led by One of the Students – 1st cycle

Having presented the processes involved in the implementation stage of this action research, the next section evaluates the impact of the implemented action plans.

4.2.4. Stage 4: Evaluation and Assessment

At the assessment and evaluation stage, the researcher related to the impacts of the three plans of actions planned and implemented in stage 2 and stage 3. Such impacts emerged in both forms, namely qualitative and quantitative results. Table 38 shows the types of assessments.

<table>
<tr><th colspan="2">First Cycle:
Evaluation and Assessment Stage</th></tr>
<tr><td>Assessment and findings of Operational Plan One</td><td>Impact of contacting non-attending students
1. Increase/decrease in attendance
2. Other findings</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Assessment and findings of Operational Plan Two</td><td>Impact of implementing the researcher's Skills-Mix design as a New way of streaming students
N/A</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Assessment and findings of Operational Plan Three (Maths knowledge Network)</td><td>Impact of creating a knowledge network in tutorials or in extra maths sessions
• Analysis of maths exam success performance
  • Quantitative comparison and Statistical graphic technique

• Assessing the change in maths skills level
  • Correlation Analysis
  • Regression Analysis
  • Analysis of fluctuations in the dynamic process of skills and confidence development
  • Analysis of fluctuations in satisfactions on support received

• Assessing the change in maths knowledge network (using UCINET)
  • Graphic technique of SNA
  • Quantitative SNA
    • Network level measures
      i. Network Density
      ii. Network Cohesion
      iii. Average distance in the network
    • Individual level measures
      i. Degree centrality
      ii. Eigenvector closeness
      iii. Flow Betweenness

• Results of assessing developments in strategies
Strategy analysis through reflection on relevant theories</td></tr>
</table>

Table 38: Evaluation and Assessment of Implemented Plans – 1st cycle

4.2.4.1. Assessment of Operational Plan 1

Although the researcher designed operational plan 1 to contact 124 students whose attendance was fewer than 5 sessions, the module leader and the BSUKU students' administrator had to carry out the plan only for those with attendance of fewer than 3 sessions, due to time constraints.

4.2.4.1.1. Results of Contacting Non-Attending Students

The students' administrator and module leader together contacted 46 students and arranged to meet them in person and discuss the issues related to their non-attending. Figure 23 shows how students responded to the emails and telephone calls from the students administrator and the module leader.

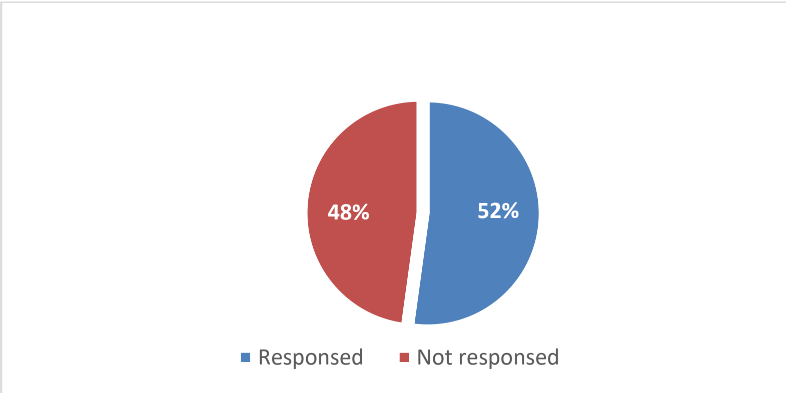


Figure 23: Response Rate to School Contact – 1st cycle

On average, the attendance rate of those who responded to the call increased to 2 sessions in semester 2, but those who did not respond had the same average of 1 session per semester (see Figure 24). In fact, the attendances in semester 1 and semester 2 had a weak correlation of r=+0.34.

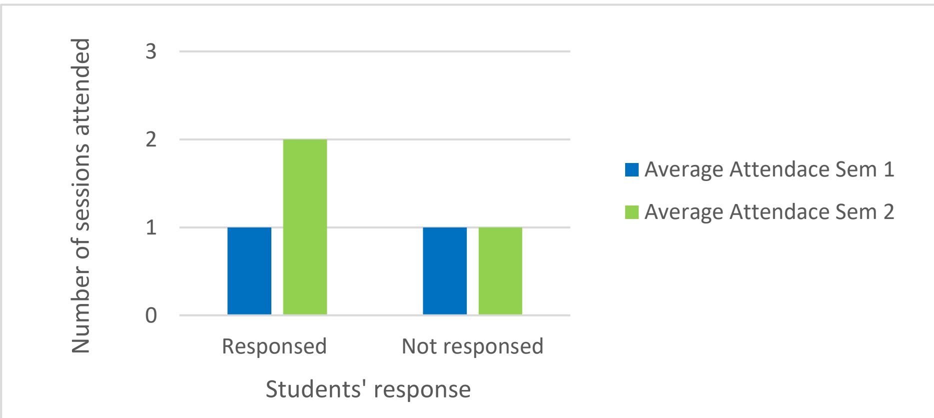


Figure 24: Operation 1, Change in Average Attendance – 1st cycle

In terms of progress in maths skill development and performance, Figure 25 illustrates a very similar trend for both categories on average. The test results and exam results were strongly correlated to one another, with r=+0.98. Total attendance for this group (low attending students), however, was not correlated much with final exam performance, since r=+0.22. In addition, it appears that the level of no-show and fail absorbed 57% of the performance (see Figure 26).

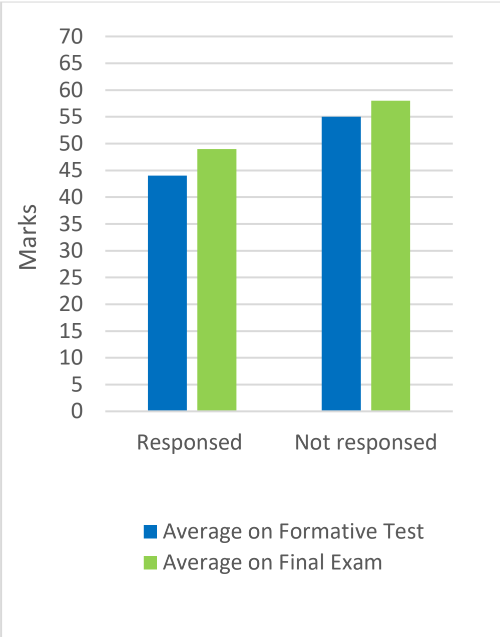


Figure 25: Operation 1, Performance Progress – 1st cycle

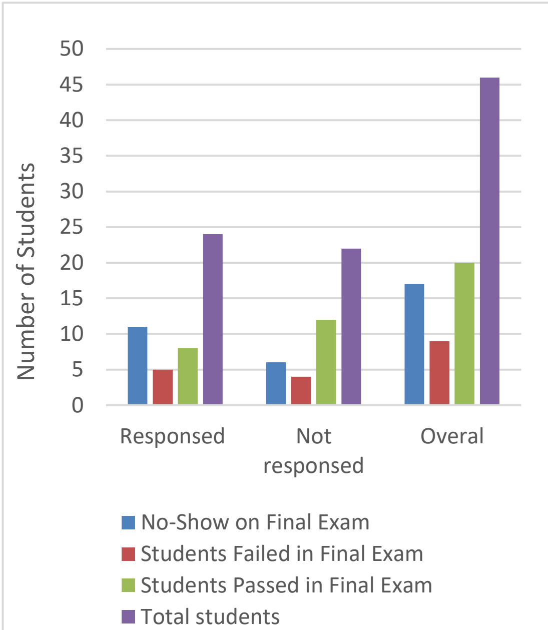


Figure 26: Operation 1, Exam Performance – 1st cycle

Digging further through the streams reveals the decrease in attendance for those in streams A and B and an increase for those in streams C, D and E in semester 2, though the highest average attendances were in 3 sessions in semester 2 (see Figure 27).

In addition, stream D, and mostly stream E, were responsible for the majority of no-shows in the formative test and final exam (see Figure 28). Further, there was not much difference in average performance for streams A, B, C and E in the formative test and final exam. However, stream D exhibited a sharp increase in average performance (see Figure 29). Moreover, as Figure 30 reveals, fails in the final exam came from streams C, D and mostly E.

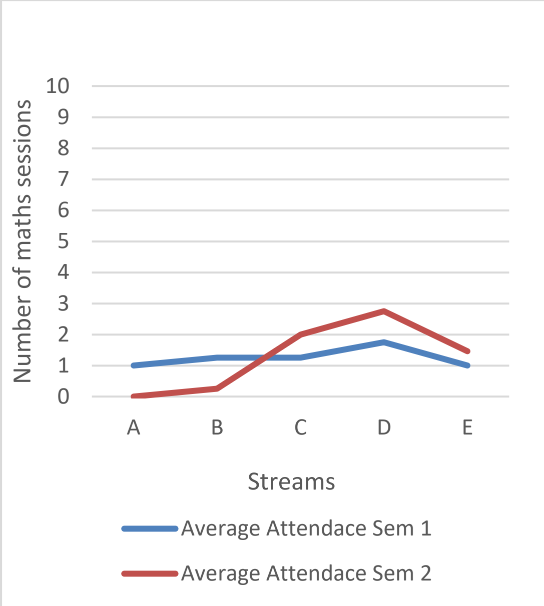


Figure 27: Change in Attendance per Stream, OP 1 – 1st cycle

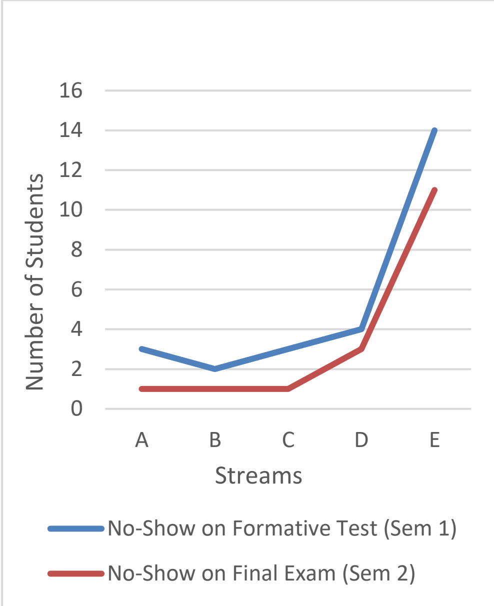


Figure 28: No-Show in Formative Test and Final Exam, OP 1 – 1st cycle

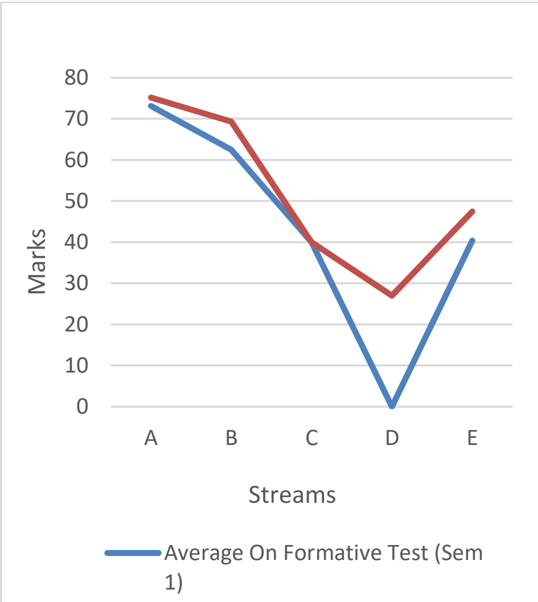


Figure 29: Average Performance in Formative Test and Final Exam, OP 1 – 1st cycle

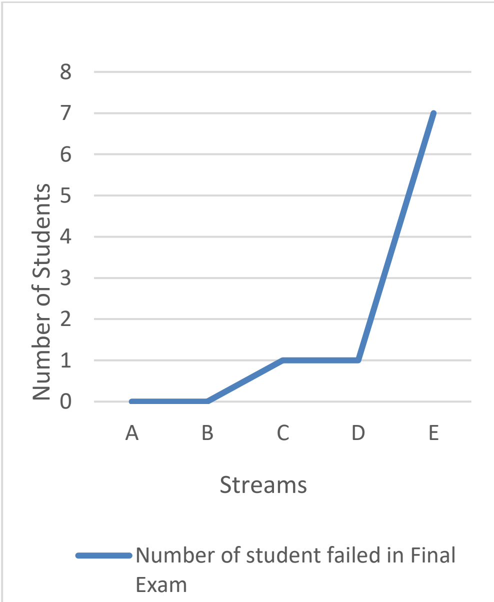


Figure 30: Students Failed in Exam Per Stream, OP 1 – 1st cycle

Overall, considering the figures above and the interview with BSUKU's administrator discussed in Section 4.2.3.1.1, it appears that implementing operational plan 1 in order to attract low-attending students has mainly revealed students' underlying personal issues and basic conditions that are to be dealt with first, in order for academic engagement to begin. The data shows that these low-attending students have mainly GCSE D, E and F grades. The university, therefore, has to offer more substantial support to those being recruited with such maths background upon admission.

4.2.4.2. Assessment of Operational Plan 3/Maths Knowledge Network

This section presents the results of various evaluations of the aspects of operational plan 3.

4.2.4.2.1. Results of Assessing Maths Exam Performance

Figure 31 illustrates the overall APS-Maths performance, whilst Figure 32 and Figure 33 represent the performance of those involved in the systemic solution (maths knowledge network) and the performance of the rest of the students, respectively. The first major change in the APS-Maths module that emerged in this arena related to the increased rate of pass for those students who participated in the maths knowledge network. The second major development was the rate of no-show.

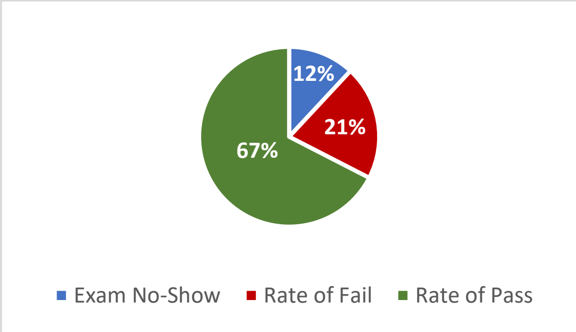


Figure 31: Overall APS-Maths Performance – 1st cycle

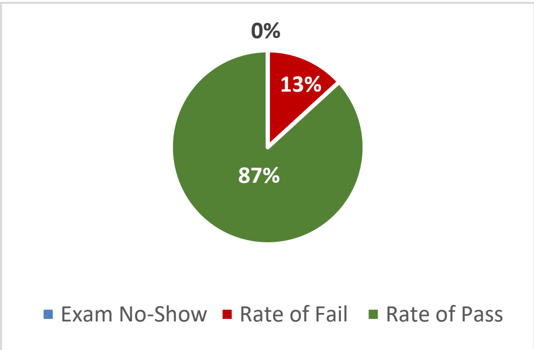


Figure 32: APS-Maths Performance, Involved in OP3 (Maths Knowledge Network) – 1st cycle

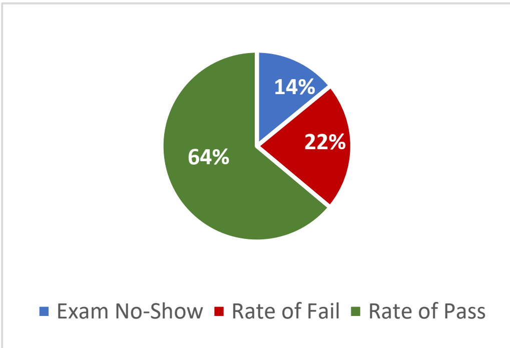


Figure 33: APS-Maths Performance, Not involved in OP3 (Maths Knowledge Network) – 1st cycle

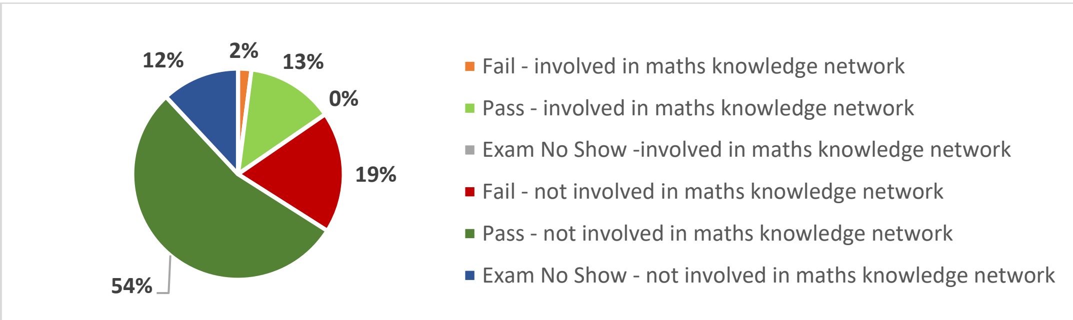


Figure 34: APS-Maths Proportional Exam Performance - 1st cycle

Figure 34 illustrates a proportional perspective on the APS-Maths final exam performance for both those involved in the maths knowledge network and those not involved. A whole student view also illustrates that those involved in the maths knowledge network had 2% fail out of the total 21% fail in APS-Maths. Further, all of those involved in the maths knowledge network attended the final exam, while there was 14% for final exam no-show among the rest of the APS-Maths students (Figure 32 and Figure 33). The researcher relates to this behaviour as increased motivation, which emerged because of the confidence gained in the process of maths skills development.

It is important to note that in order to appropriately compare the result of those who attended the maths knowledge network and those who did not, a control group needs to be used. However, in this research it was not practically possible to select a control group because of ethical factors involved in the process. The BSUKU policy for students' equal treatment and uniformity did not allow the plan for the maths knowledge network to be implemented only for a particular group of learners (even if randomly selected), with the rest excluded. In addition, the social field environment gives a greater degree of freedom to individuals, in contrast with laboratory research. Similarly, in the present research, attendance was not compulsory. Hence, non-equivalence of the experimental groups and the control group could easily happen. Further, experimenting in the social field is more difficult since the unit of intervention shifts from an individual to a larger group, such as teams or communities, etc. (McKillip, 1992). Nonetheless, in order to partially compensate for the infeasibility of having a direct control group, a literature review on self-organisation within socio-technical teams has been provided in Section 2.3.3.6.1. The studies reviewed are similar to this research, which supports the claim that if teams are self-organised and make their own decisions within the context of the agreed goals and objectives, they perform better than teams which are not self-organised. Further, despite not having a direct control group, the design of this action research happened to have pre-test and post-test features which created some opportunities to consider and discuss certain results.

The researcher created four exam mark bands and used a paired two sample t-test to obtain the means of each band (see Appendix 13 and Appendix 14). The effect size of each t-test was then calculated, which supported the provision of some indicative inferences in this research. Chart 6 shows the mean differences between the formative test and the final exam per mark band for those involved in the maths knowledge network (OP 3) and those not involved (all P-values were less than 0.05). Table 31 shows the effect size of the mean difference for each mark band.

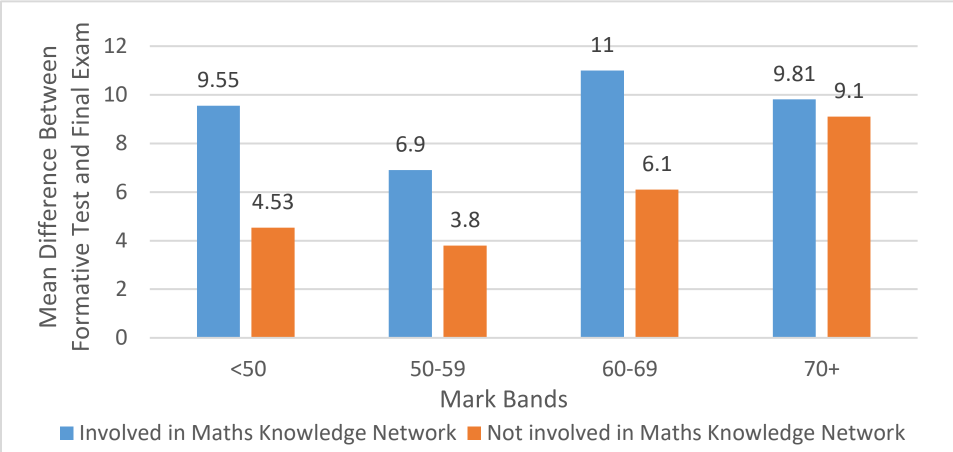


Chart 6: Mean Differences per Mark Band – 1st cycle

Bands of Mark	Effect size – In maths knowledge network	Effect size - not involved in maths knowledge network
<50	1.74	0.76
50-59	2.33	0.59
60-69	1.1	1.07
70+	2.1	0.96

Table 39: Effect Size of Mean Differences per Mark Band

Chart 6 shows that, in each mark band, those who participated in the learning network were able to increase their performance more than those who did not participate. Whilst it is not surprising to observe that the average increase for those in band marks 60-69 and 70+ being involved in the maths knowledge network was high, it appears that the average increase for those in band mark <50 was also high; in fact, it was double the figure for those who did not participate in the maths knowledge network.

In addition, according to Table 39, the size effect of the mean difference in each mark band for those who participated in the maths knowledge network was greater than that for those who did not participate in the maths knowledge network. The size effect is a means for quantifying the difference between the two groups. It measures the strength of an intervention. It is important to note that an effect size of 0.2 to 0.5 is considered as a small effect. The effect size of 0.5 to 0.8 shows a medium effect and the effect size of 0.8 and higher refers to a large effect. The higher the effect size, the stronger the relationship between an intervention and an outcome. The effects size here in this research conveys the estimated magnitude of a possible relationship. Effect size, however, makes no statement about the true relationship.

4.2.4.2.2. *Results of Assessing Change in Maths Skills Level*

The researcher performed correlation and regression analyses on the data gathered at each session. Table 40 shows the results of these analyses, whilst Figure 35 illustrates the fluctuations in the process of maths skills and confidence development.

	Confidence rate - start	Skills rate - start	*Confidence rate - end*	*Skill rate - end*	How happy the team is with support received from each other	*How happy the team is with support received from Facilitator*
Confidence rate - start	1.000000000					
Skills rate - start	0.896227165	1.000000000				
Confidence rate - end	0.865231978	0.821264630	1.000000000			
Skill rate - end	0.807462026	0.856505111	0.921313499	1.000000000		
How happy the team is with support received from each other	0.370019782	0.310824025	0.427470057	0.401174978	1.000000000	
How happy the team is with support received from Facilitator	0.314426290	0.255527794	0.332712470	0.322399346	0.664370126	1.000000000
SUMMARY OUTPUT FOR: SKILLS RATE - END						
Regression Statistics						
Multiple R	0.945728913					
R Square	0.894403177					
Adjusted R Square	0.892539703					
Standard Error	0.471039568					
Observations	174					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	319.4818428	106.4939476	479.9656386	1.01265E-82	
Residual	170	37.71930663	0.221878274			
Total	173	357.2011494				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.624998752	0.190750506	3.276524739	0.001273984	0.248454066	1.001543437
Confidence rate - start	-0.28952935	0.059018184	-4.905765156	2.16465E-06	-0.406032231	-0.173026469
Skills rate - start	0.439649644	0.051561214	8.52675117	7.91605E-15	0.337866946	0.541432342
Confidence rate - end	0.789854547	0.050370546	15.68088109	7.47226E-35	0.690422247	0.889286847

Table 40: Correlation and Regression Analysis for Skills Rate-End in APS-Maths OP3 (Maths Knowledge Network) – 1st cycle

As the purpose of the systemic solution was to develop the maths skills, the skills developed at the end of each session were important. Table 40 shows that skills and confidence at the end of the sessions were strongly correlated to skills and confidence at the start of the sessions (all correlation coefficient values were greater than 0.81). In this arena, regression analysis reveals that the skills developed at the end of the session related to a combination of confidence at the start (r=-0.29), skills at the start (r=+0.44) and confidence at the end of each session (r=0.79), as they all had p-values less than 0.05 (with a coefficient of determination r-square of 0.89). The negative weak correlations between confidence rate at the end of the session and the skills developed at the start of the sessions might be an indicator of fear and stress about maths, resulting in a small loss of confidence among students at the start of each session. With F-significance being less than 0.05, ANOVA also suggests that the means of skills and confidence levels perceived at the beginning of the sessions were different to those at the end of the session. The observation number of 174 represents the number of times data was collected from the learners who organically attended the extra maths sessions.

Figure 35 shows that skills and confidence development accelerated after progressing through two thirds of the sessions. In addition, Table 41 reveals that students' satisfaction regarding the facilitator's support was correlated to their satisfaction with the support received from peers (with r =+66).

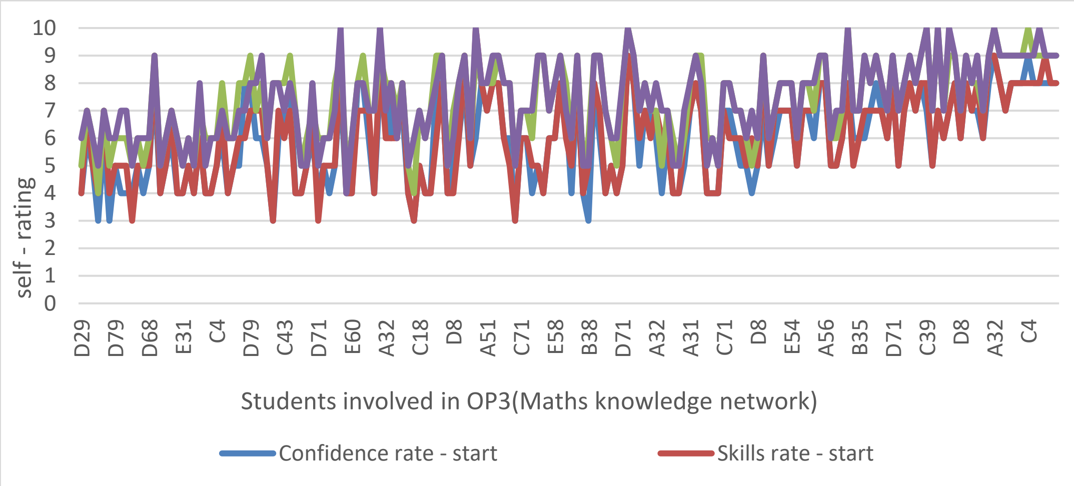


Figure 35: Fluctuations in the Process of Skills and Confidence Development in OP3 (Maths Knowledge Network) - 1st cycle

Regression analysis provides further reference to said correlation.

SUMMARY OUTPUT FOR: HOW HAPPY THE TEAM IS WITH THE SUPPORT RECEIVED FROM FACILITATOR						
Regression Statistics						
Multiple R	0.664370126					
R Square	0.441387664					
Adjusted R Square	0.438139918					
Standard Error	0.986018934					
Observations	174					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	132.1321877	132.1321877	135.9058393	1.62008E-23	
Residual	172	167.2241341	0.972233338			
Total	173	299.3563218				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.714400271	0.33081576	14.25083338	6.23518E-31	4.061418865	5.367381676
How happy the team is with support recived from each other	0.471300903	0.040427717	11.65786598	1.62008E-23	0.391502567	0.55109924

Table 41: Regression Analysis for Satisfaction with Facilitator's support in OP3 (Maths Knowledge Network) – 1st cycle

Since the r-squared is 0.44, therefore 44% of the data on how happy teams are with the support received from the facilitator can be explained through the data on how happy teams are with the support received from each other in the team. Hence, the two components are associated together with a positively moderate strength. This might refer to a particular part of the facilitator's role, namely arranging the team structures so that they could support each other, along with other roles. Figure 36 illustrates the fluctuations in the satisfaction with the support received from peers or from the facilitator.

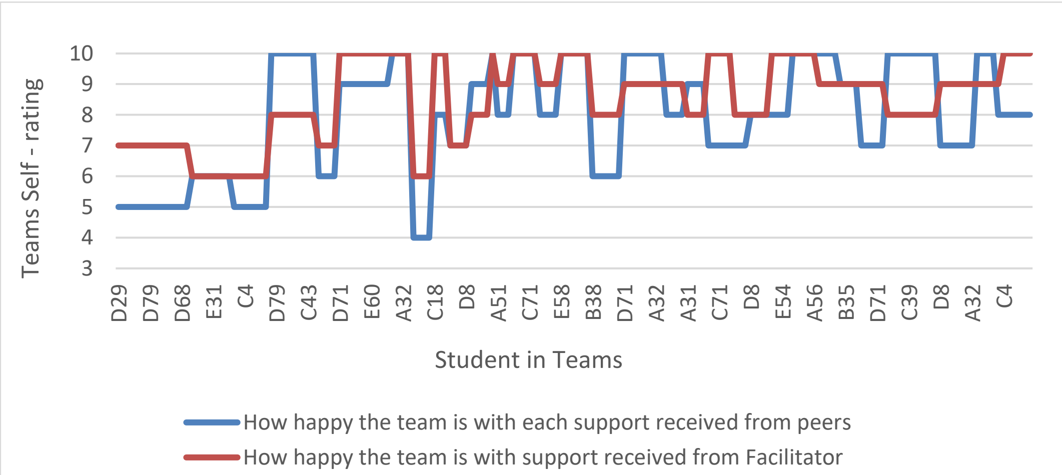


Figure 36: Fluctuations in the Satisfaction with the Support Received from Facilitator and from Peers in OP3 (Maths Knowledge Network) – 1st cycle

The following section provides further illustration on help seeking cases in the teams and across the teams along the course of extra maths sessions through a basic social network analysis.

4.2.4.2.3. Results of Assessing Change in Maths Knowledge Network

The researcher performed a basic social network analysis in order to reveal the changes in the maths knowledge network after the actions/operations. Figure 37 reveals the underlying structure of said knowledge network. Teams are shown in dark blue squares and individual students are the red circles. This graph was developed based on every 5 students who organically formed a team together in each session. The only adjustment was that if there was not a highly-skilled student in the team, the researcher advised them to swap places among teams to maintain the ratio of 1:4. This happened only in the initial sessions. After the first week, they naturally assembled their team accordingly. Since in each session they reported who was in their team on the feedback forms, it was possible to use this data and to develop Figure 37, comprising all of the sessions.

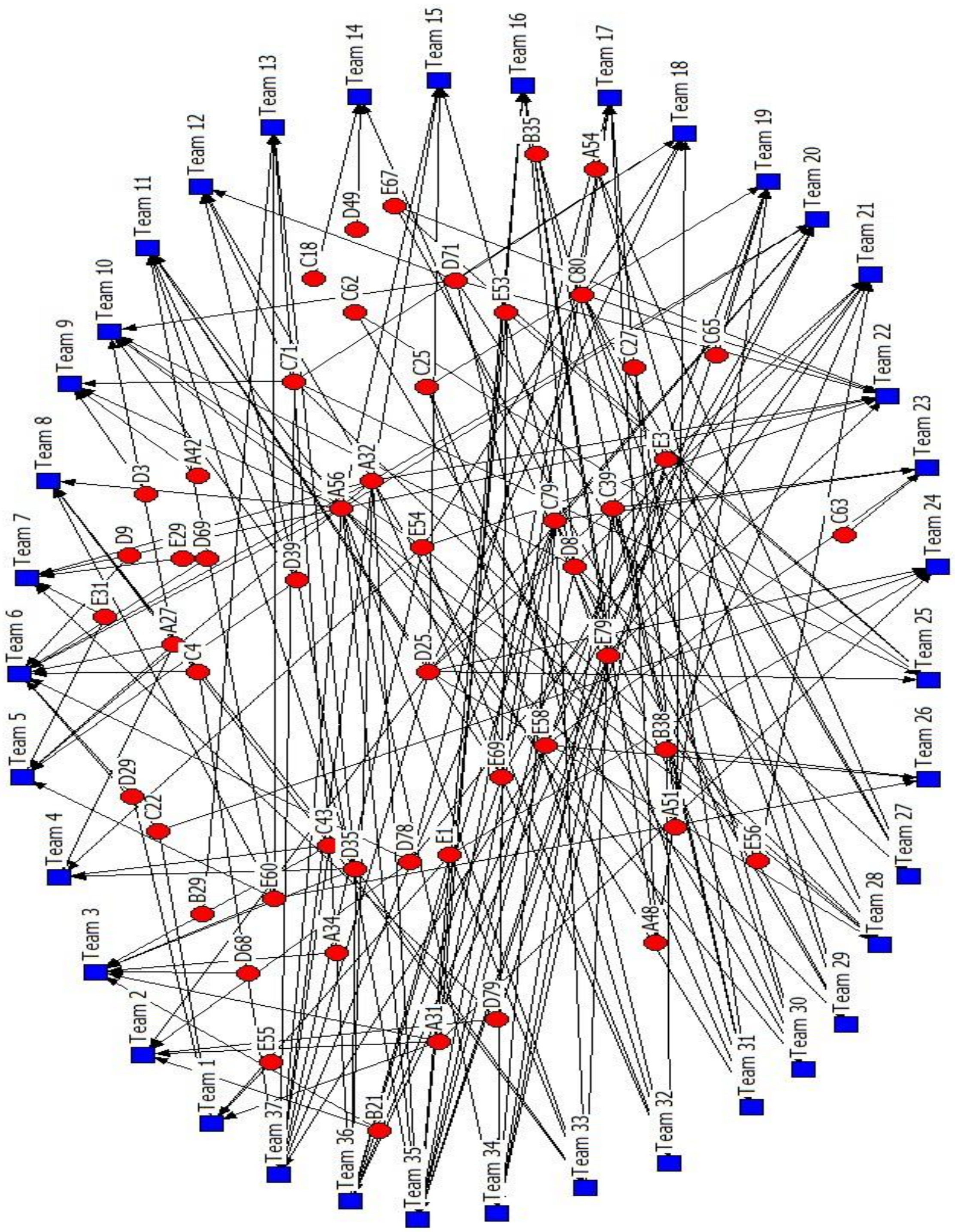


Figure 37: Students Attending Different Teams Throughout the OP3 (Maths Knowledge Network) – 1st cycle

It is evident that knowledge sharing and collaborative experiential learning/practice occurred within teams and expanded further across teams. It is important to note that the 37 teams were arranged throughout the sessions. Hence, the team numbers also show the order of team creations through time.

In addition, Figure 38 illustrates which teams are the key components of the network in connecting students together, without which some students may be disconnected from the network. In this graph, all normal components, whether teams or individuals, are represented in red colour. Those in blue colour are the cut-points. As discussed in Section 2.2.2.1, cut-points are nodes, and if they are removed, the network will break into detached segments. Blocks are the parts/segments that are produced by a cut-point.

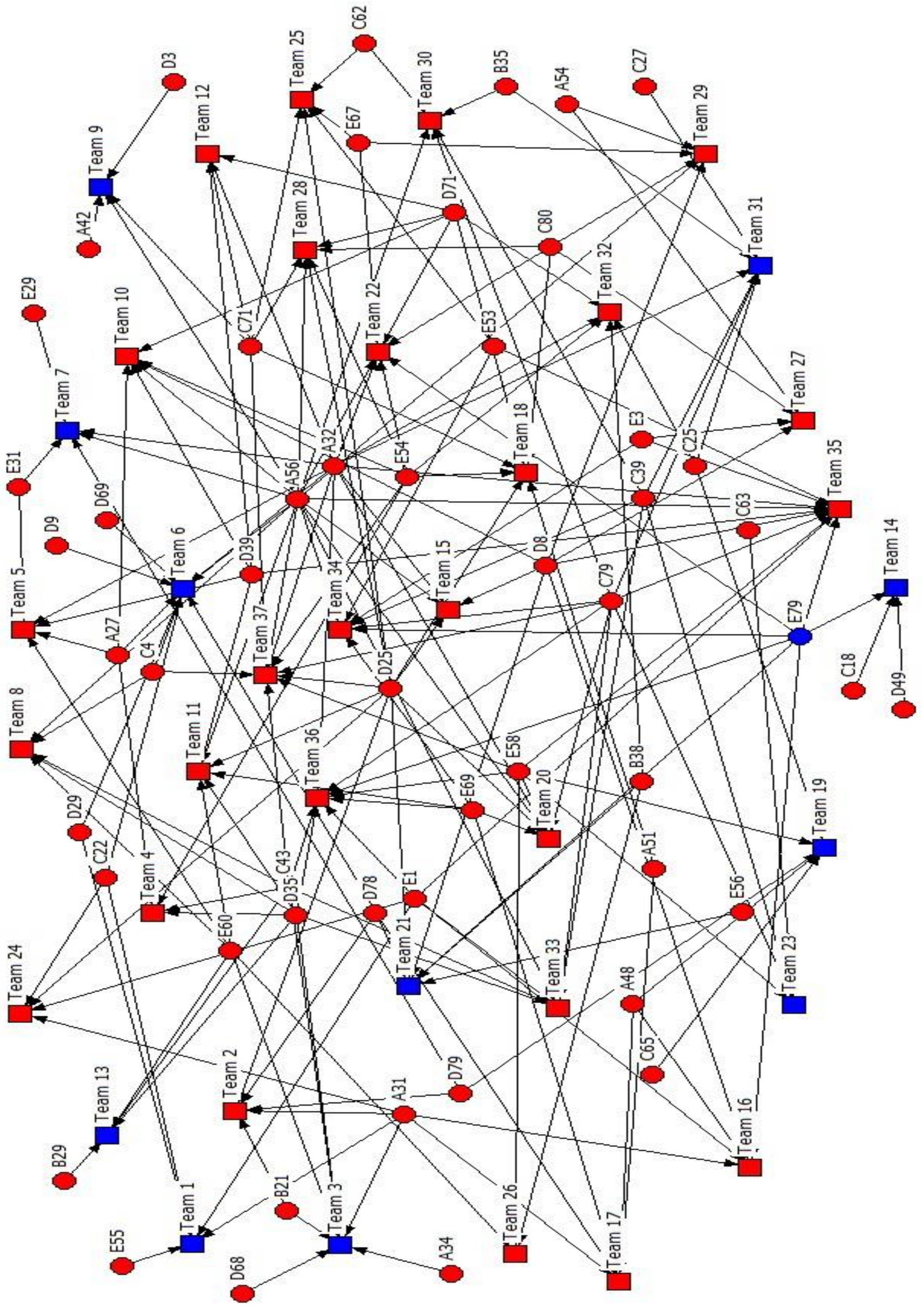


Figure 38: Blocks and Cut-Points in Maths Knowledge Sharing Network, OP3 (Maths Knowledge Network) – 1st cycle

It is evident that 11 teams were in critical positions to keep everyone connected throughout the sessions. There is also one individual (E79) who connected two other individuals (C18 and D49) in team 14 with six other teams, i.e. teams 16, 21, 22, 34, 35 and 36 (with reference to his/her presence and hence knowledge in team 14). Therefore, he/she connects subgroups together.

In order to understand the level of connectivity among students, the researcher reflected on their network of ties. Figure 39 shows the total ties which emerged in collective knowledge sharing and collaborative learning/practice.

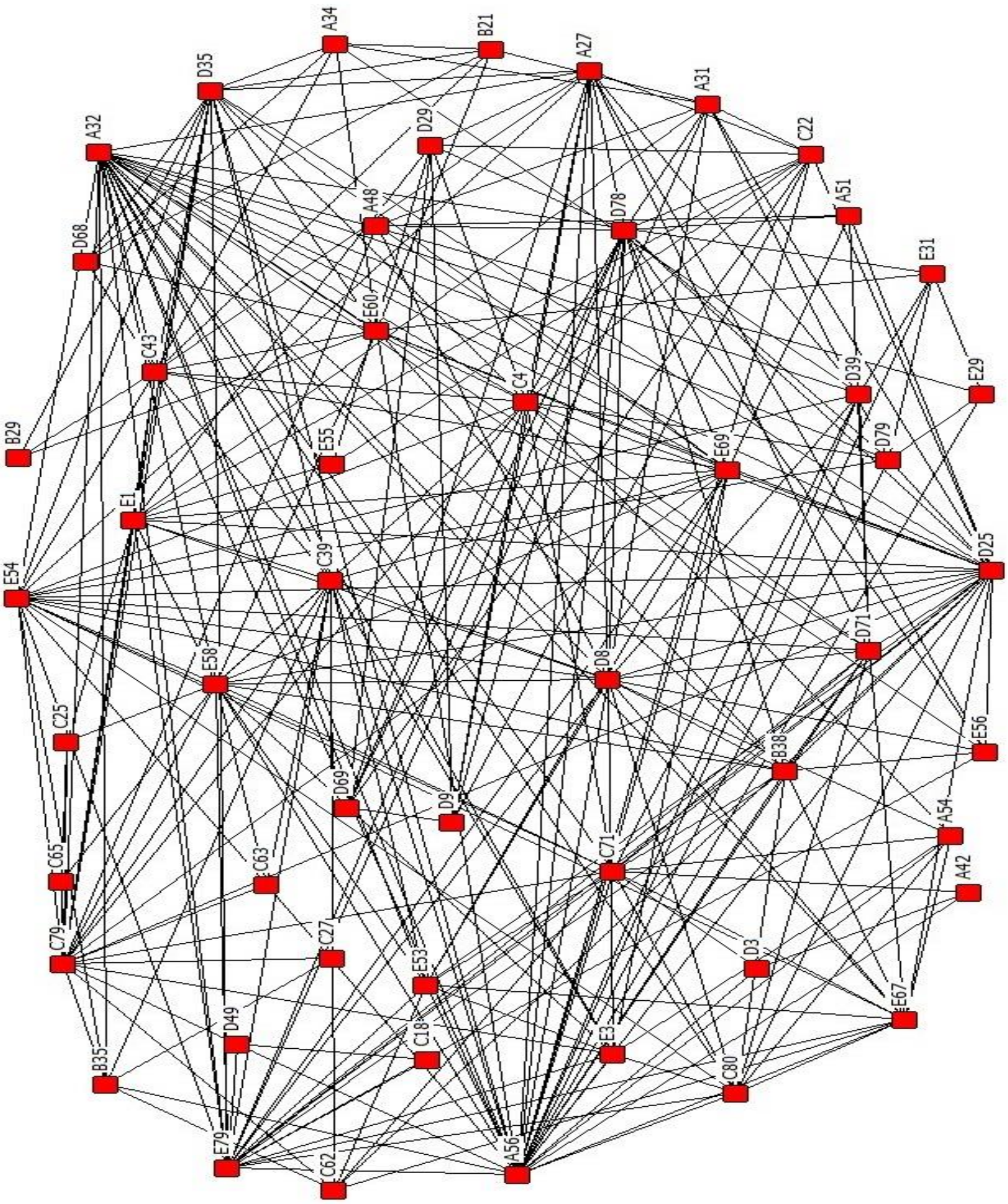


Figure 39: Ties that Emerged in Knowledge Sharing and Collaborative Learning /Practice, OP3 (Maths Knowledge Network) – 1st cycle

Figure 40 represents the strength of student ties in the maths knowledge network. This graph was developed based on the data gathered in each and every session through individual feedback forms. The data came from answers to a question on this form which asked: who was most helpful to you in your team (see Appendix 6)? The width of the ties in each of the pairs is an indicator of the number of times each student found the other one satisfactorily helpful in knowledge sharing and collaborative experiential learning, and hence had stronger ties. Indeed, a weaker tie represents communications and a stronger tie shows helpfulness and effectiveness.

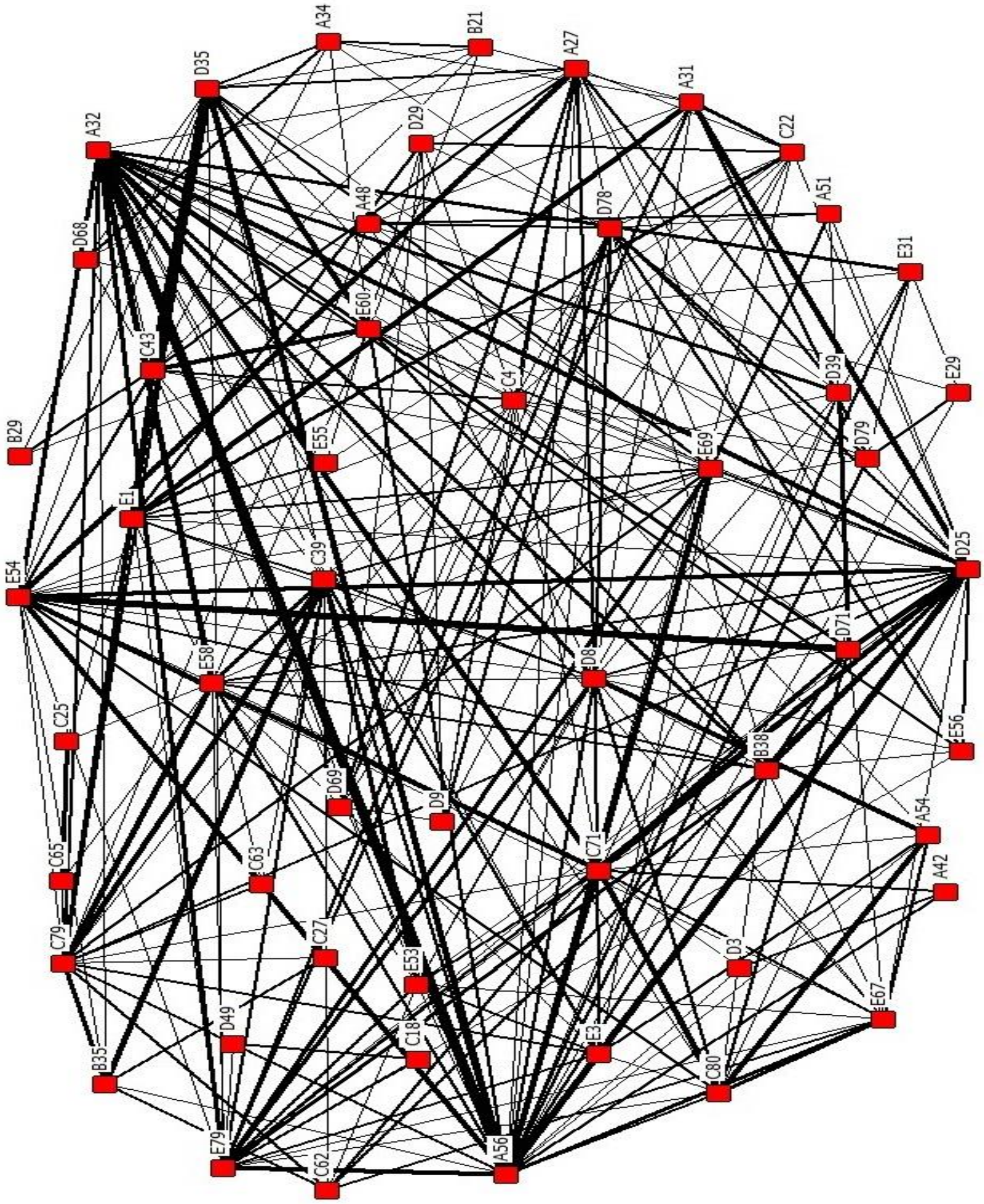


Figure 40: Strength of Student Ties in the Maths Knowledge Network, OP3 (Maths Knowledge Network) – 1st cycle

In terms of measures of the network, Table 42 offers the features of the maths knowledge network.

Density	32%
Distance-based Cohesion	0.553
Average Distance	2.079

Table 42: Connection Measures, Knowledge Network – 1st cycle

Density refers to the number of ties as a percentage of the number of pairs in the network and reveals the level of information/knowledge flow through the pairs. The density of 32% for a network is considered a healthy level because it promotes knowledge sharing. As Burt (1992) suggests, a healthy density does not generate redundant information. Overly dense networks in comparison would be more relevant when tight control is needed, yet they are ineffective for generating new and innovative solutions. In addition, with reference to a network's distance-based cohesion, it can be stated that the concerned knowledge network has a considerable cohesion level of 55.3%. In qualitative terms, this figure means that agents of the networks are quite well-connected and engage/interact together well. The average distance relates to the average number of steps in order to access all participants in the network. The average distance of 2.079 in the network shows that, on average, in two steps everyone can be reached. It therefore indicates that collective knowledge sharing and collaborative experiential learning/practice between highly-skilled and low-skilled students in the knowledge network are highly likely.

From the perspective of individual connections, the researcher used three main measures, namely degree centrality, eigenvector closeness and flow betweenness. Table 43 shows the degree centrality measure.

	1st Actor	2nd Actor	3rd Actor
In-Degree	A56 = 65	A32 = 49	D25 = 41
Out-Degree	D25 = 55	A32 = 44	A56 = 41
NrmInDegree	A56 = 15.93	A32 = 12.01	D25 = 10.05
NrmOutDegree	D25= 13.48	A32 = 10.78	A56 = 10.05
Network Centralisation (Indegree) = 12.106%	Network Centralisation (Outdegree) = 9.607%		

DESCRIPTIVE STATISTICS

		1 Out Degree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
1	Mean	16.56	16.56	4.06	4.06
2	Std Dev	13.06	13.11	3.20	3.21
3	Sum	861.00	861.00	211.03	211.03
4	Variance	170.52	171.79	10.24	10.32
5	SSQ	23123.00	23189.00	1389.07	1393.03
6	MCSSQ	8866.83	8932.83	532.66	536.62
7	Euc Norm	152.06	152.28	37.27	37.32
8	Minimum	3.00	2.00	0.74	0.49
9	Maximum	55.00	65.00	13.48	15.93
10	N of Obs	52.00	52.00	52.00	52.00

Table 43: Degree Measure, Knowledge Network – 1st cycle

Micro level of analysis: The highest in-degree values referred to agents A56, A32 and D25 in that order. Most of the other agents often related to these three actors for discussion respectively. This indicates that these three agents are in the position to be asked for help. In addition, agents D25, A32 and A56 had the peak out-degrees respectively. The high out-degrees suggest that they can be considered as the most influential agents.

Meso level of analysis: With reference to distribution of agents' degree centrality, the mean of agents' degree was 16.56. This is very moderate, since there are 51 other actors. In addition, with reflection on standard deviations and variances, it is observed that the variability across the agents in in-degree was slightly more than the variability across the agents in out-degree and that the range of in-degree was a little bigger than that of out-degree. These measures justify the structural homogeneity or heterogeneity in a network. Here, the coefficient of variation was 79% for both in-degree and out-degree. Therefore, the network appears to be heterogeneous in influence (out-degrees) and prominence (in-degrees).

Macro level of analysis: The graph degree centralisation indicates the overall integration of the network. In more centralised networks, economy of scale is important and in less centralised networks speed, flexibility, local regulations and accomplishment are prioritised. Network centralisation measures show how unequally the degrees are spread out as a percentage. Here the out-degree and in-degree centralisation of the network were 9.6% and 12%, respectively. This evidence which makes it possible to conclude that there is no substantial concentration in the network. In other words, the power of individual agents does not differ significantly. Therefore, positional advantages of knowledge level are evenly spread out in the network.

Hence, another impact of the methods used in the OP3 (maths knowledge network) is the improvement in the knowledge network structure. This is through a change from highly centralised classrooms/lectures around the main figure, i.e. the lecturer, to a quite decentralised network structure where students with diversified levels of maths knowledge are connected together. In this scenario, skills development and performance betterment did speed up locally using learning/practice accomplishments in self-organised teams. This is in line with the plan of arranging teams with a 1:4 ratio of highly-skilled to low-skilled students, which has now shown its impact in the whole maths knowledge network.

Table 44 refers to eigenvector geodesic closeness to find the most central students who are globally influential in the overall structure of the knowledge network. This is to complement the degree centrality measure. Whilst degree centrality refers to locally influential students, Eigenvector closeness extends the scope of the centrality measure to the overall network. According to the eigenvector closeness analysis, the scores of Eigenvectors reveal the more central agents. Here, A56, A32 and D25 were the most central students in the knowledge network.

	1st Actor	2nd Actor	3rd Actor
Eigenvector closeness	A56 = 0.39	A32 = 0.35	D25 = 0.32
Network Centralisation Index = 48.39%			

	1 Eigen Value	2 % of Variance	3 Cum %	4 Ratio
	-----	------	-----	------
1:	33.76712	26.8	26.8	2.117
2:	15.95044	12.7	39.5	1.268
3:	12.58137	10.0	49.5	1.259

Descriptive Statistics

		1 Eigenvec	2 nEigenve
		--------	--------
1	Mean	0.10	14.43
2	Std Dev	0.09	13.28
3	Sum	5.31	750.40
4	Variance	0.01	176.37
5	SSQ	1.00	20000.00
6	MCSSQ	0.46	9171.17
7	Euc Norm	1.00	141.42
8	Minimum	0.01	1.03
9	Maximum	0.39	55.24
10	N of Obs	52.00	52.00
11	N Missing	0.00	0.00

Table 44: Eigenvector Closeness, Knowledge Network – 1st cycle

Micro level analysis: The eigenvalue approach provides a tidied-up form of measure for closeness centrality. Referring to the first eigenvector scores, the greater the score, the more central the agent is among all the agents in the key pattern of distances. Here, A56, A32 and D25 represented the most central agents in the leading pattern.

Meso level analysis: The eigenvalues assert how the general pattern of distances among agents is reflective of global patterns, and more local/extra patterns. Percentage of general variation in distances for the first agent is important. Here, the first Eigenvalue had 26.8% in terms of overall percentage of distances. This suggests that the main pattern in the knowledge network emerges from a little more than one fourth of all distances and indicates that the leading pattern is not extensive. The first Eigenvalue was 2.1 times higher than the second Eigenvalue. This indicates that the leading pattern is 2.1 times more significant than the secondary pattern. Since the leading pattern was at least 1.5 times larger than the second pattern, the centrality measure is considered robust.

Macro level analysis: The Network centralisation index for the knowledge network was moderate (48.39%), which implies the level of concentration in the distribution of agent centrality and power. This is normal in the knowledge network, since low-skilled students were referred to, and asked for help from, highly-skilled students. When they discovered whom the most reliable sources of knowledge were, the number of referrals to these particular sources/agents increased; hence, some additional and stronger ties were created that led to more concentration on these three agents' centrality. However, the 48.39% network centralisation was not very moderate. It would not cause problematic inequality for the defined purpose of the network in developing maths skills and improving performance.

Table 45 relates to flow betweenness centrality. This measure accepts that agents will adapt all of the pathways linking them, based on proportion of the pathways' lengths.

	1st Actor	2nd Actor	3rd Actor
Flow Betweenness	E79 = 242.57	C79 = 192.27	A56 = 151.51
Flow nBetweenness	E79 = 9.51	C79 = 7.54	A56 = 5.94
Network Centralization Index = 7.465%			

DESCRIPTIVE STATISTICS FOR EACH MEASURE

		1 FlowBet	2 nFlowBet
1	Mean	55.89	2.19
2	Std Dev	47.15	1.85
3	Sum	2906.03	113.96
4	Variance	2223.17	3.42
5	SSQ	278009.31	427.54
6	MCSSQ	115604.82	177.79
7	Euc Norm	527.27	20.68
8	Minimum	1.86	0.07
9	Maximum	242.57	9.51
10	N of Obs	52.00	52.00

Table 45: Flow Betweenness Measure, Knowledge Network – 1st cycle

The flow betweenness provides another picture of the knowledge network. Evidently, E79, C79 and A56 were the most key mediators for knowledge flow (the importance of E79 in knowledge flow is because it is a cut-point in the network). In addition, based on the descriptive statistics in Table 45, the coefficient of variation for flow betweenness of students was relatively high (0.84). Nonetheless, the degree of concentration/inequality in the spreading of flow betweenness within the knowledge network was as low as 7.465%. In other words, knowledge flows in the network quite smoothly.

4.2.4.2.4. Results of Assessing Developments in Strategies

Throughout the implementation of the domains of viable knowledge, as discussed in Section 4.2.3.1.3.2, students were empowered based on feedback loops that they created in each session on their collaborative knowledge sharing and cooperative experiential learning/practice. This empowerment manifested itself in terms of team and class strategies that they developed for their progress in maths skills development and performance improvement. Figure 41 shows the gradual development of strategies.

Figure 41: Gradual Developments in Strategies, Knowledge Network – 1st cycle

It is evident that the journey of maths skills development and performance improvement started from knowledge sharing and learning in teams and led to a strategy for debates and discussions in the full class. The implementation of systemic actions/operations then ended with the two emergent phenomena, as discussed in Section 4.2.3.1.3.3.1 and Section 4.2.3.1.3.3.2. The next section provides the reflection, lessons learned and the discussion on the four stages in the first cycle of the SCOR methodology to close the first cycle. The researcher will use the insights and lessons from the first cycle to feed into the second cycle.

Stage 5: Reflection and Learning

At this reflection and learning stage, the researcher refers to the impacts of the earlier four stages and the cycle is settled. Such impacts emerged from both the qualitative and quantitative results. The researcher used an interpretive approach to understand each of the impacts and to link them together in a pragmatist way. The new insights generated through the interpretations are discussed at this stage.

First Cycle: Reflection and Learning Stage	
Reflection and Learning from Stage One	Learning from Systemic Diagnosis
Reflection and Learning from Stage Two	Learning from Operation/Action Planning and Design
Reflection and Learning from Stage Three	Learning from Implementing the Actions/Operations
Reflection and Learning from Stage Four	Learning from Evaluation and Assessment

Table 46: Reflection and Learning – 1st cycle

Carrying out stage 1, i.e. diagnosis, the researcher reached a deep understanding of the context, structures and issues for the skills/competencies/performance situation in APS-Maths at BSUKU. According to viable system diagnosis, management of students' learning processes and their cognitive capital was undermined by the meta-system (teaching management). In this arena, the ethnographic observations provided rich insights into diverse learning processes and featured norms in different students' streams. In addition, analysis of clusters of students revealed that the type of students-streaming strategy is creating a structural fracture in their learning system. Hence, the missing link among strongly-skilled and low-skilled students hindered/blocked the flow of quality maths knowledge. The collective of identified issues is presented in Table 30.

Taking the findings from the diagnosis stage into account, the researcher designed a systemic solution for maths skills development and performance improvement. This was achieved through performing a quantitative analysis of APS performance data for the last three years using Beer's (1972) actuality, capability and potentiality measures of the system. In addition, dimensions of students' social capital were considered. The availability of cognitive capital was used to more realistically design and plan the operations/actions. In this vein, maths teachers/specialists do know how to use students' attendance (with different cognitive capital levels) data in order to increase the likelihood of creating and designing an effective knowledge mix and learning/practicing scenarios. However, the researcher discovered that non-maths specialists, including the module leader at BSUKU (who admitted she does not know much about maths teaching) are less interested in differentiating the type of maths knowledge (as an interplay between tacit and explicit) from other types of knowledge. This is one of the major issues when a meta-system attempts to design learning/teaching methods. In addition, the researcher used domains of viable knowledge in order to structure the functionalities of the collaborative learning/practising sessions. Ultimately, the result of this stage was three operational plans. Operational plan 1 was to approach those who did not attend at least half of the maths workshops in the first semester, so as to investigate the causes and to motivate them to attend in the second semester. Operational plan 2 was about timetabling strategy and the planned details for the second semester based on which a ratio of 1:4 for highly-skilled to low-skilled students could be created in each workshop and tutorial (this ratio was designed based on their attendance rate). Said underlying desired structure could facilitate operational plan 3. Operational plan 3 (which later became well-known as the maths knowledge network), comprised facilitating a session for a basic understanding of the viable system model among students, creating goals, purposes and identity as well as an interpretation of domains of viable knowledge in the context of learning. The latter was a method of collaborative knowledge sharing in guided self-organised teams, which leads to learners' skills development and performance improvements.

In terms of implementation in this research, operational plan 3 was dependent upon the successful implementation of operational plan 2. Yet, the university's change agenda could not maintain the plan since the timetabling team was technically not able to stream students according to operational plan 2. Hence, an agreement was made with the module leader to implement operational plan 3 through providing extra maths sessions (maths knowledge network) rather than via tutorials.

The researcher evaluated the impacts of implementing plans 1 and 3 (the timetabling team could not execute operational plan 2). In terms of operational plan 1, it was understood that those who attended fewer than three sessions in the first semester had some personal conditions that obstructed their attendance. The administrator and the module leader had discussed the different types of help available, including the opportunity of attending extra maths session in their communications with these students. However, it was revealed that these students did not attend the extra maths sessions. This suggests that there are other priority issues among these students. The interviews showed that personal, financial and job schedule issues were affecting the situation. The researcher learned that help in resolving their issues could be provided centrally through the university's student services rather than at BSUKU. Reflecting on the impacts of operational plan 3 (i.e. the maths knowledge network), it is evident that the plan gained success in skills development and performance improvement. Table 47 presents the level of change in maths performance for those who participated in the extra maths sessions (systemic solution).

Admission	Teaching/Learning Structure	Rate of Fail
2012-2013	Maths Workshops	16.25%
2013-2014	Maths Workshops	20.00%
2014-2015	Maths Workshops	26.15%
2015-2016	Maths Workshops + Tutorials sessions	22.00%
	Maths workshops + Tutorial sessions + Systemic solution	13.00%

Table 47: Change in Rate of Fail – 1st cycle

With reference to the viable system performance measurement (see Section 4.2.2.1.1), it was evident that APS-Maths, as the evolving system, underperformed in terms of reaching students' success performance rate of 82% (because 78% < 82%). It was therefore understood that merely adding tutorials to the structure of the APS-Maths module was insufficient in terms of improving the maths exam performance. Instead, the group of students who participated in the systemic solution (in the extra maths sessions/maths knowledge network) and the workshops and tutorials, outperformed with regard to students' performance compared to those who did not attend the systemic solution. Their success rate was 87%, which was clearly above the 82% expected performance.

In addition, the researcher learned that the systemic solution based on the combination of the viable system model and social network analysis could create a heterogeneous structure in the students' knowledge network (see Section 4.2.4.2.3). The next impact was establishing the high level of cohesion (0.55) and considerable density (32%) achieved in the maths knowledge network.

Further, the action research made it clear that students were truly empowered in taking control of their own and collective learning. This is because the method helped them to create a meta-system for their knowledge network. They recognised the progress made in maths skill development. It was their own judgment to compare their abilities/skills throughout the sessions.

With real progress made, agent A56 appeared to develop himself/herself into a 'knowledge leader' when he/she offered to run the last two sessions using a method similar to that employed by the researcher. The code of this student shows that he/she was from group A (stream 1) and that his/her maths knowledge was A-level A to C. Hence, he/she was a highly-skilled student. In addition, social network analysis showed that he/she was one of the most influential (measure of degree centrality), powerful/central (Eigenvector degree closeness measure) and key knowledge mediators/brokers (flow betweenness measure). Therefore, actor A56 is called a knowledge leader, justified based on both practical terms and academic analysis. According to social network analysis, it is also predictable that if the systemic solution would have continued for a few further sessions, A32 also might have shown some interest in leading a session; this is because he/she was the second best in most of the measures mentioned above. The knowledge network was also heterogonous. A56 was one of the key agents in the leading pattern (slightly more than 1/4) of the network. Another key agent was A32, who could develop more ties to become a knowledge leader, along with A56. Similarly, agent C39, who also initiated self-reproduction of the system for skills development in the accounting and finance module, joined the session at the later stage (after session 10). It is predicted that, if he/she was present from the start of the extra maths sessions, his/her social network measures would have likely ranked him/her among the first three in all three measures.

The researcher presented the results of the systemic solution to the module leader and the teaching team on 28th June 2016. The possibility of carrying out the same solution for the next academic year was also discussed. The module leader stated that for the next academic year timetabling might still not be able to help with streaming students based on the required knowledge mix in operational plan 2. It was therefore concluded that the researcher would be better off in practice if next year the solution could be through operational plan 3, i.e. extra maths sessions and creating the knowledge network in order to facilitate maths skills development and performance improvement.

Finally, carrying out the first cycle of SCOR at BSUKU, the researcher learned that improvement in quantitative results is more important in the eyes of the module leader than qualitative and emerging outcomes. However, the researcher suggests that they each contribute equally to development of the other.

4.3. Section 2: Second Cycle (2016-17) Case Study

This section of the SCOR methodology refers to the second case study. It comprises five stages, namely diagnosis, action planning, implementation, evaluation and reflection/learning, similar to the first cycle. Since the organisation site of the second case study is the same as the first cycle, and the researcher used the information, plans, analysis and learning of the first cycle, the components, structures and conditions have not changed. The descriptions will not be replicated here so as to avoid unnecessary rewriting and re-analysis.

4.3.1. Stage 1: Diagnosis

Table 48 shows the data collection methods and tools, as well as the data analysis method for this stage.

Second Cycle: Diagnosis stage	
Data Sources, Collection Methods and Tools	Ethnographical Observations, Workshop facilitation notes, Interviews, Student Streaming Data, First Semester Attendance and Performance Results

Data Analysis Methods	**Viable Systems Diagnosis (Beer, 1985; Espinosa and Walker, 2013):**
	• Identifying system in focus and system's identity
	    • Identifying System 1
	    • Identifying meta-system
	• Illustrating the network map of meta-system
	• Mapping issues in System 1
	    • Using meta-systemic questions relevant to System 1
	• Mapping issues in the meta-system
	    • Using meta-systemic questions relevant to system 2, 3, 4 and 5
	• Explore and interpret the network
	Qualitative SNA - Describing Ethnographic Observations :
	• Coding qualitative data
	• Exploring and Identifying the processes in System 1
	• Describing the qualitative processes in System 1
	• interpreting the processes in System 1
	Quantitative SNA - Graphic Network Description with UCINET :
	• Coding the quantitative data
	    • Clusters: Visual illustrations of system 1 quantitative data
	• Interpreting the patterns of issues in system 1

Table 48: Second Cycle: Diagnosis Stage, Data Collection and Data Analysis Methods – 2nd cycle

4.3.1.1. Process

For the academic year 2016-17, the module leader invited the same teaching and tutorial teams from year 2015-16 for the APS planning meeting on 13th September 2016. This meeting was to reorientate everyone so that everything was the same as the previous academic year. The tutors cooperatively decided on a schedule of work based on their availability. In this meeting, it was also decided to have a quick maths test to gauge students' current knowledge rather than relying on their highest past maths qualification. The teaching team was responsible for designing the questions and the test was to be taken at the end of students' induction session on 4th October 2016. With regard to marking the test, teaching and tutorial teams were involved. Similar to the year before, the induction session was a collective assembly of new students, where they were introduced to the APS module, the module leader, the researcher, and other immediate stakeholders required for running and supporting the APS module. The process of this session was the same as the year before. The only difference was the new students. In the first semester, the researcher and the other two tutors each facilitated 18 maths workshops from 12th October 2016 to 20th December 2016. There were 356 students registered for APS in 2016-17 and they were allocated to five streams, as shown in Table 49.

Stream	No. of Students	Test Mark Range
1	49	62 – 80
2	57	40 – 62
3	84	37 – 58
4	85	14 – 47
5	81	0 - 41

Table 49: APS-Maths – Student Streaming – 2nd cycle

Although the researcher was informed that the timetabling would try (if possible) to allocate students to groups randomly, it appeared that the randomness was not effective enough. Based on Table 49, the skills-mix in each stream was different from that of the other streams. Evidently, stream 1 contained the highly-skilled students. The low-skilled students were in streams 2, 3, 4 and 5. Stream 5 appeared to be the most concerning one. Hence, the pattern of groping students in the second cycle suggests that all strong students were separate from the others.

4.3.1.2. Finding

For the diagnosis stage of the SOCR methodology in the second cycle, the researcher used the results of the viable system diagnosis (Beer, 1985; Espinosa et al., 2013) gathered in the first cycle. This was because the structures and processes in system 1 and the meta-system did not change for the academic year 2016-17. Here, therefore, the system in focus, the system's identity, system 1 and the meta-system, as well as the diagnosed issues (discussed in Section 4.2.1.2.1 and Section 4.2.1.2.2) remained the same for the second cycle case study of this action research. However, since the second cycle's participants were students who had been newly admitted to the school, ethnographic observations of their learning processes in each student stream (system 1) in the first semester were performed to describe the processes.

4.3.1.2.1. Ethnographic Observations: Processes in the Students' Streams

In order to provide an account of the learning processes of the students from each stream, the researcher performed ethnographic observations from 12th October 2016 to 20th December 2016. Similar to the year before, the observation helped in reaching insights into learning processes specific to students in the cohort of 2016-17. These insights could then feed into the design of relevant structures and mechanisms for collaborative knowledge sharing and skills development.

Stream 1 (Group A):

Stream one, identified as group A, comprised 49 students whose marks in the quick maths test ranged from 62 to 80. The researcher observed the maths workshop of this group on Friday 9th December 2016. The workshop started at 13:00 and ended at 14:50. It was observed that:

> *"Students were very quiet and focused during the whole session whether in lecture slots or in the exercise time. They knew the maths theories and application of the concepts very well when solving MyMathLab exercises. Only three students asked for help from the tutor in the exercise intervals. Two of the issues were about simple arithmetic errors and the other pertained to technical problems with signing into MyMathLab. They were quick to answer the questions and the answers were correct. 26 students out of 35 present in the session (74%) used pen and paper to answer the questions, despite the fact that MyMathLab was online. They all merely concentrated on the online pages for MyMathLab and the APS module. No student-to-lecturer or student-to-student communications was observed. No mobile or distracting device was in sight. 27 students (77%) finished all exercises early and asked if they could leave early".*

Stream 2 (Group B):

Stream two, i.e. group B, consisted of 57 students. Their marks on the quick maths test were in the range of 40 to 62. Through an observation on Thursday 8th December 2016 at 16:00 to 15:50, it was revealed that:

> *"Students' ability to solve the exercises was very good. They know the concepts too. Six students asked questions. Three wanted to make sure their method of applying theory to the*

exercises were correct. Two of them asked questions about the concept to clarify the right formula and the method to apply it. Another one referred to the application of quadratic equations and discussed why he has not reached the correct answer. This student asked for another example from the tutor to fully understand the concept and its application. 25 students out of 40 present in this session (63%) used pen and paper to answer the questions on MyMathLab. Two students were whispering/chatting with each other. Hence, there was a little noise at the exercise intervals. The class, however, was quiet at the lecturing intervals. There were five mobiles seen on students' desks. The students used them sometimes".

Stream 3 (Group C):

This stream, known as group C, contained 84 students. In the quick maths test, students' marks ranged from 37 to 58. On Friday 9th December 2016 at 15:00 to 16:30, it was observed that:

"There were 53 students present in the session. Students had a moderate level of maths knowledge, both in terms of concepts and in application. In total, 24 people asked tutors and the lecturer for help at the exercise intervals. Out of these 24 students, 6 students did not know the concept of compound interest at all and 9 of them did not know how to apply the formula. There was a need to explain the contents further through extra examples for those who struggled to understand the concept and the application. 50% of those present (27 out of 53) used pen and paper to solve maths questions on MyMathLab. Behaviourally, whilst students were quiet at the teaching intervals, a little distracting noise was heard at the exercise intervals in the back corners of the class. Five students were talking about something irrelevant to the maths session. Although MyMathLab was open on their screens, other pages (online games) were also open and active. In addition, four students used a mobile in the session".

Stream 4 (Group D):

Stream 4, identified as group D, consisted of 85 students. Their marks on the quick maths test ranged from 14 to 47. The researcher observed this stream on Wednesday 7th December 2016 at 11:00 to 12:15. It was revealed that:

"There were 50 students present in this session. Their maths knowledge in terms of concepts and application was below average. Only 20 out of 50 (40%) did use pen and paper to solve the questions. Tutors and the lecturer responded to 20 calls for help at the exercise intervals. 40% of the calls were about issues in understanding the concept of compound interest as well as simultaneous equations, whilst 60% related to the application of the concepts concerning the questions at hand on MyMathLab. Observing lack of skills at the exercise intervals, the lecturer suggested to the whole class to book one-to-one tutorials with the library skills team if they felt less confident and struggled with particular topics in maths. Noise was evident in this session, as all of the back seats were chatting to each other. Online shopping webpages, games and Facebook were observed open and active on the screens of eight students. In addition, 10 students were disengaged because of using their mobile in the class".

Stream 5 (Group E):

Stream 5 was identified as group E. There were 81 students assigned to this stream. Their marks on the quick maths test ranged from 0 to 41. Through an observation on Thursday 8th December 2016 at 11:00 to 12:50, it was found that:

"There were 45 students attending this session. Their maths knowledge was concerning. Half of students (24 of them) were very confused on the concepts as well as application of the rules/procedures in the questions at hand. Students expressed their lack of confidence, fear and stress about maths lessons to the tutors. The lecturer asked all to each book an appointment with the library skills team if they were struggling. Only eight students used pen and paper to complete the exercises on MyMathLab. On one occasion in a teaching slot, half of the students were chatting with each other. Their chat was not relevant to the maths lesson. The class was very noisy. The tutor had to ask the lecturer to stop in order to reorientate/re-engage those talkative students who were not listening to the lecturer at the teaching interval. Social media webpages were open on screens (10 students). Three students left the class. It appeared normal to use/play with mobiles (15 students)".

The ethnographic observations described above were brief accounts of the norms in the teaching/learning processes of each stream. Reflecting on these accounts, it was evident that stream 1 represented highly-skilled students. Their norms of using pen and paper for solving maths questions, as well as not using mobiles/social media/games in the session, could help to produce a deeper focus on the questions at hand. These norms were not widespread in other streams and the lack of focus was clear (particularly in streams 4 and 5). Stream 4, and particularly stream 5, were in a concerning state due to lack of sufficient knowledge of maths concepts and procedures. Streams 2 and 3 were generally on the safe side in terms of both moderate prior maths knowledge and level of focus. However, if students in streams 4 and 5 could create and maintain the culture and conditions to focus in the maths workshops, it would have been possible to learn the concepts and apply the mathematical notions in order to solve the questions at hand. This was not happening in streams 4 and 5 at all. Attendance in streams 4 and 5 was also not satisfactory. With the maths contents being interlinked, it was vital for them to attend every single workshop. Hence, absence was a big risk for students in stream 5. In terms of communication, there was no goal for student-to-student communication that could orientate them towards the maths learning. Therefore, the level of distracting noise, especially in stream 5, was high. In this arena, it was highly recommendable to create guided/supervised communication and collaborative learning mechanisms to improve maths performance. This is because communication is a double-edged sword. Creating connections among the five groups of skill-mix could challenge the misconceptions through guided students' communications/debates/discussions. In addition, lack of confidence in streams 4 and 5 was evident. Through communications and interactions, the lack of confidence could be reduced, when quality maths knowledge could be shared among students with different skills (if the skills-mix could be arranged in all streams). Evidently, similar to the first cycle, the second cycle of APS students did not have such arrangements. Overall, it appeared that the dynamic learning processes in each stream of the second cycle were similar to those of the first cycle.

4.3.1.2.2. Cluster Assessment of the Streams

This section provides the situation in the students' network. The researcher wanted to better understand the structures and relations within system 1 in the second cycle.

4.3.1.2.2.1. Clusters: Visual Illustrations of the Streams

Figure 42 visualises how 356 students were streamed in five groups, namely A, B, C, D and E. The colours of the nodes show the range of marks for each stream. Dark blue is for the highest marks. As the blue colour becomes lighter, the marks decrease. The light green, phosphoric green, yellow and orange all indicate lower marks, respectively. Dark red indicates the lowest mark.

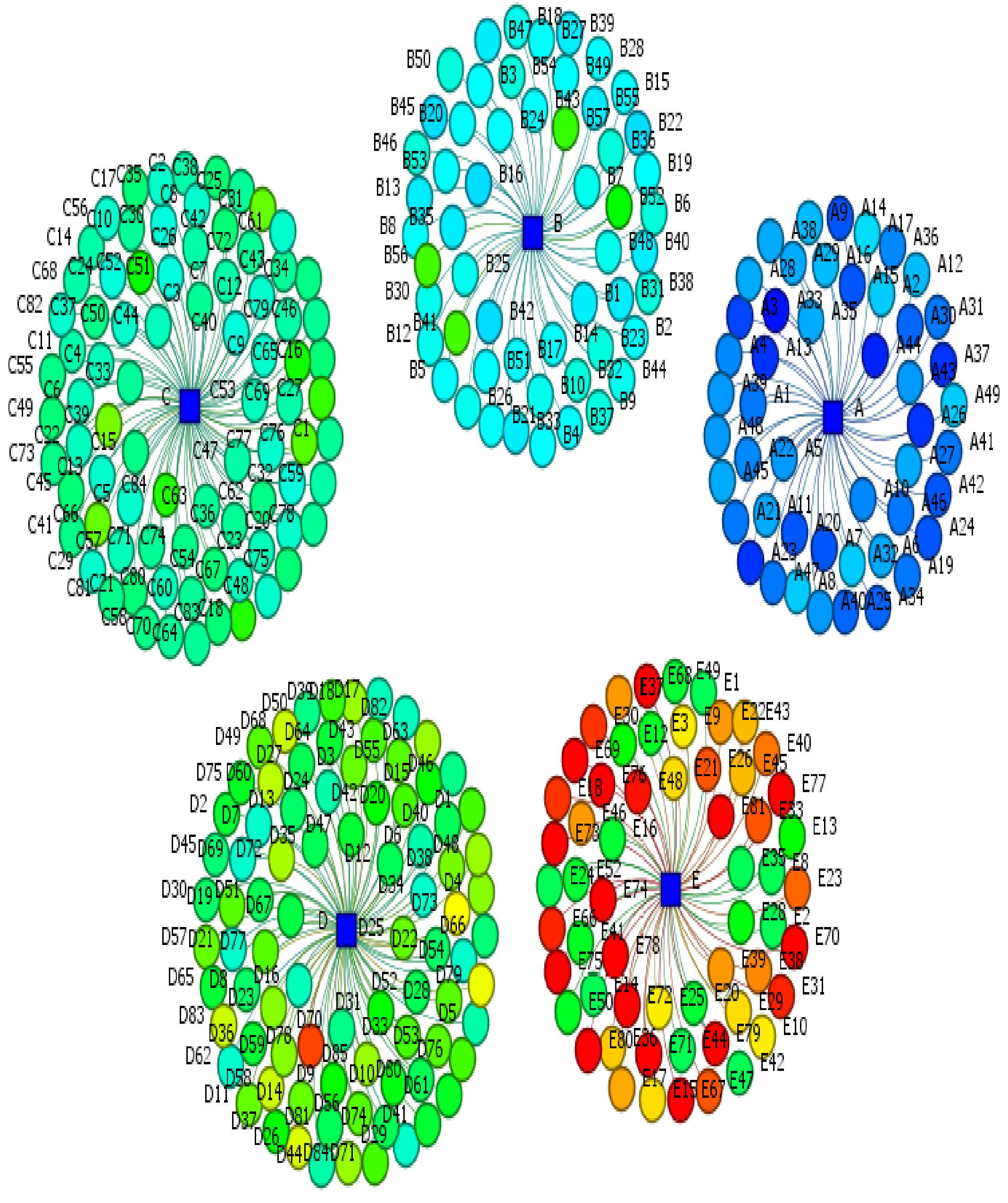


Figure 42: Clusters of First-Year students – APS-Maths Streaming – 2nd cycle

Figure 43 illustrates how students performed in the quick maths test. 30 students were absent on the day. The scattered nodes indicate their absence. The colour codes for Figure 43 are the same as for Figure 42. The sizes of the nodes show how high or low the marks have been. The researcher found streams D and E, and particularly stream E, in a critical situation.

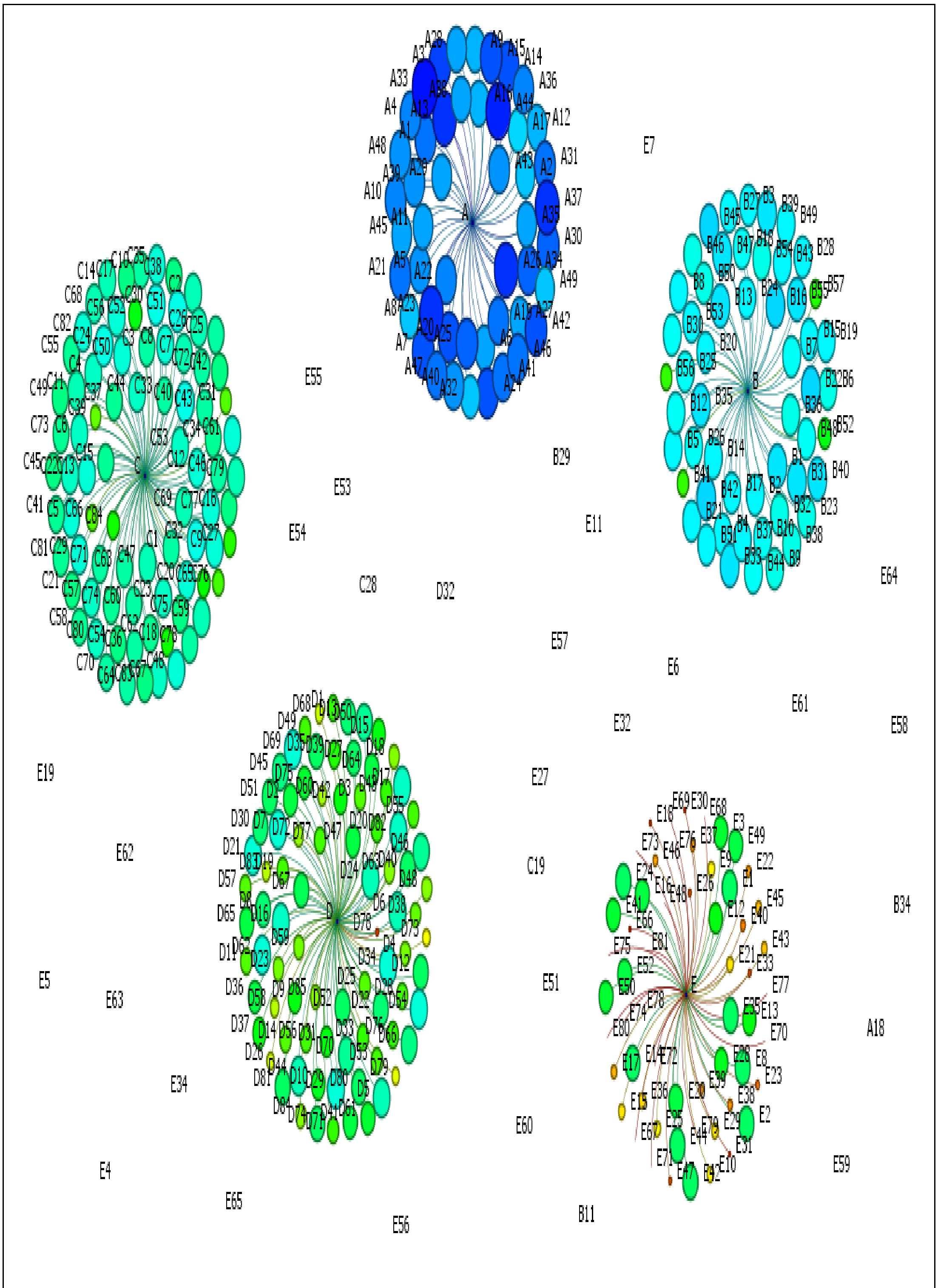


Figure 43: APS-Maths Formative Test, First Semester – 2nd cycle

In addition, since a measure of access to learning/developmental tasks is attendance, Figure 44 refers to the attendance of students in the second cycle. The sizes of the nodes reflect attendance in each stream and the colours of the nodes depict students' marks in the formative quick maths test. Dark blue shows the highest mark. Light blue, phosphoric green, light green, yellow, orange and dark red illustrate lower marks, respectively. Of the 10 maths workshops planned for APS-Maths by the module leader, 41 students did not attend any of them. Evidently, attendance in stream E was the lowest.

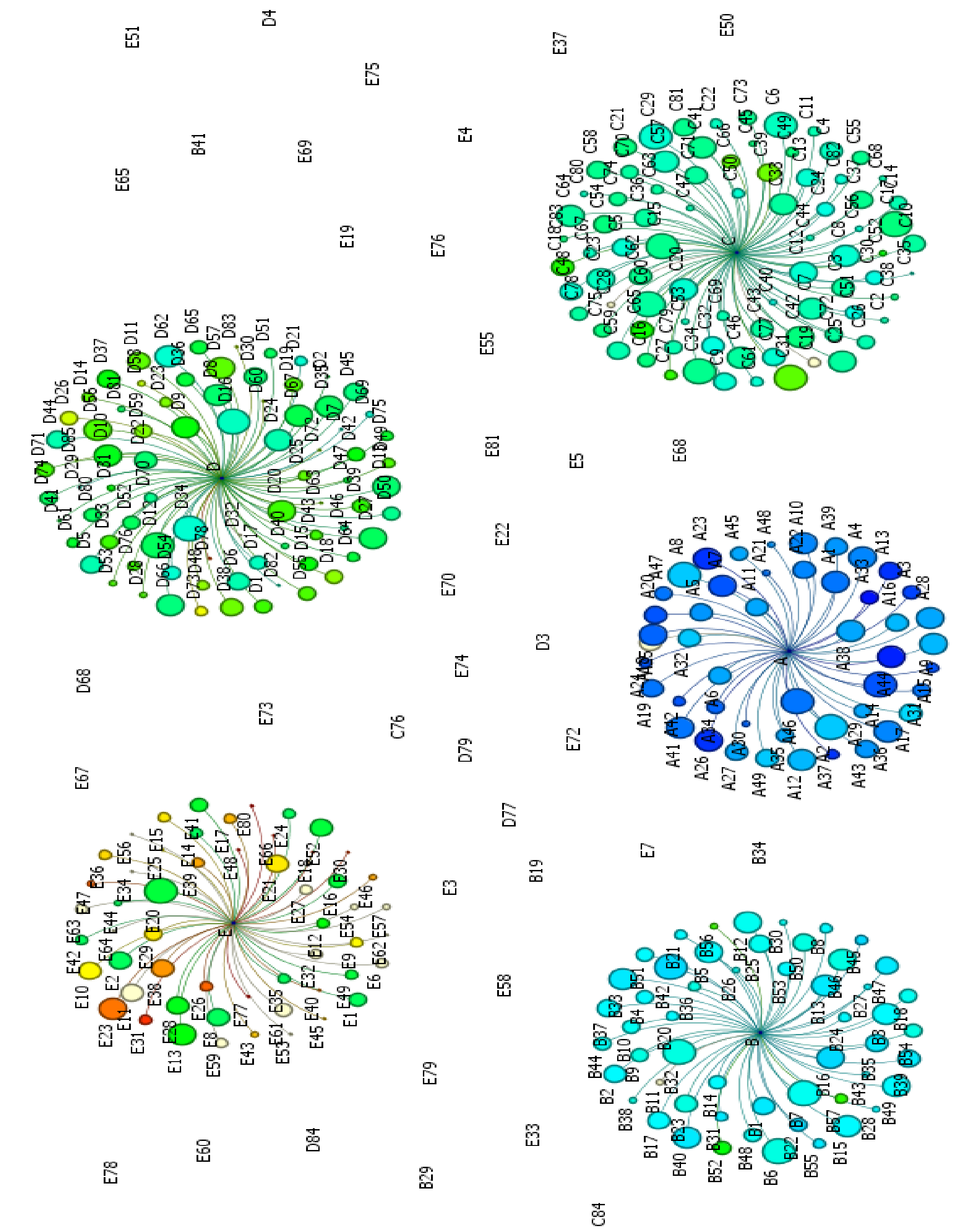


Figure 44: APS-Maths Students' Attendance – 2nd cycle

Further, since maths' concepts are connected/interlinked together, continuous attendance at maths workshops was vital. The researcher therefore decided to investigate how many students attended at least five maths workshops.

Figure 45 shows this situation. It appears that 222 students attended fewer than 5 workshops. It is also evident that stream E was in a concerning state in terms of attendance.

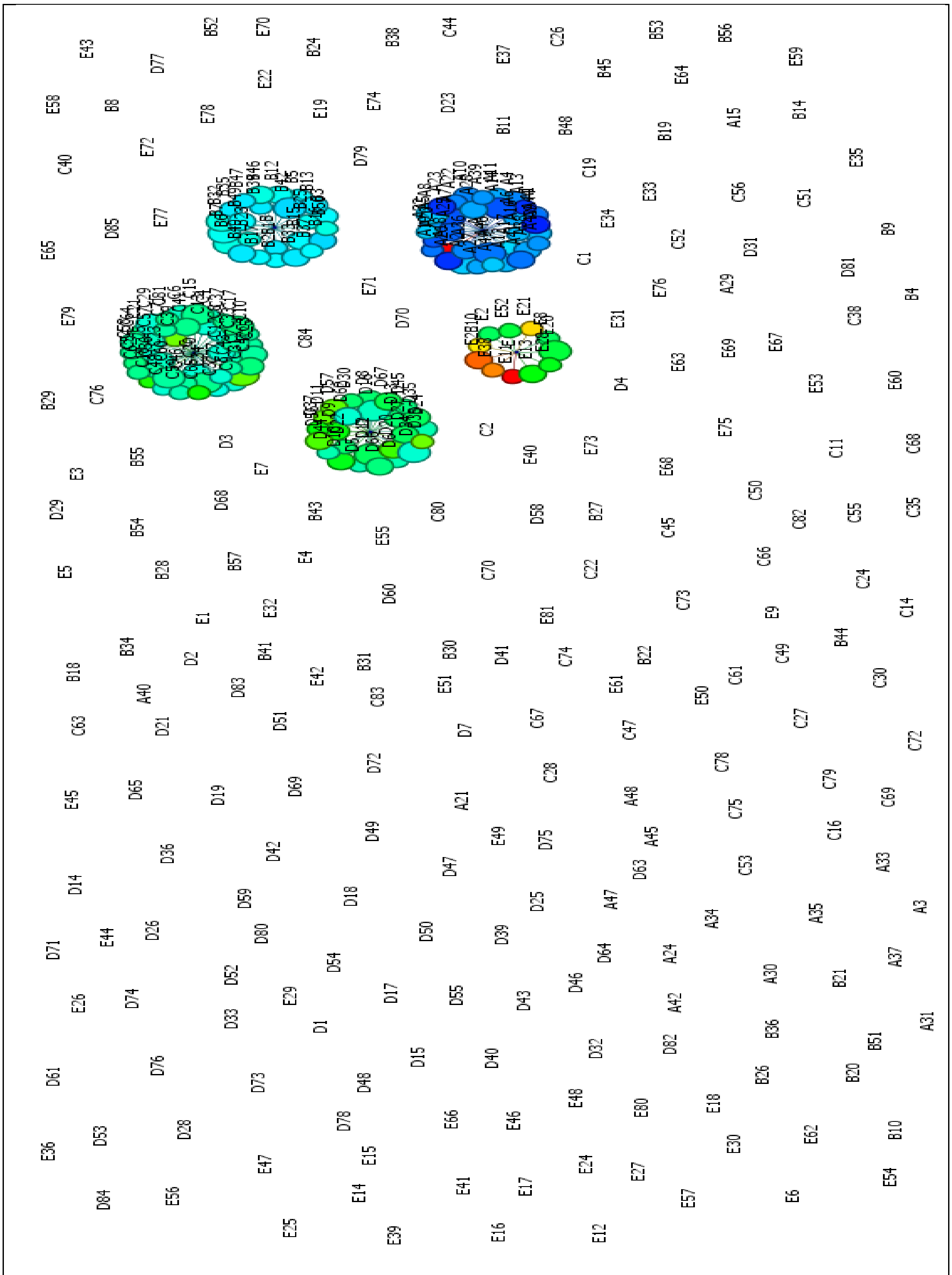


Figure 45: APS-Maths Students' Attendance (More than Five Sessions) – 2nd cycle

Table 50 also shows that the attendance of those in stream D and stream E was very low.

	Stream	Attending 5 maths sessions or more	% out of 356	Attending Less than 5 maths Session	% out of 356
Highly-Skilled	A	33	9.3%	16	4.5%
Low Skilled	B	24	28.3%	33	57.9%
	C	41		43	
	D	25		60	
	E	11		70	
Total		134	37.6%	222	62.4%

Table 50: Rate of Access to Maths Skills Development Sessions – 2nd cycle

In addition, the clusters, as shown in Figure 42, Figure 43, Figure 44 and Figure 44, revealed that there was no relation/connection between students in stream A and students of the other streams. This was not in favour of stream D, and certainly not in favour of stream E, whose students had much lower maths skills. Hence, quality maths knowledge flow and collaborative experiential learning based on mixed skills were hindered.

Overall, the patterns and trends of the streams in the first and second cycle were the same. Management of students' social capital was therefore inefficient due to the type of student streaming. In other words, effective organisation/connections of cognitive, relational and structural capital in the students' network were sacrificed. Similarly, sharing/learning from the underlying norms/practices that govern the learning in each stream was also obstructed. Evidently, students' streaming strategy and timetabling (i.e. structural capital) were the key obstacles in both cycles. The only difference in the two cycles was having the formative test at the very beginning of the semester in the second cycle. Since the test was taken at the end of the induction session, where almost all students attended, many more students took the test compared to the formative test in the first cycle. Hence, the researcher and the module leader could better understand the current level of the students' maths skills. In addition, since it was a paper-based test, this was an extra step (though the only) in recognition of aligning the type of test during the semester with the type of test in the final exam. However, choosing the level and type of questions was not in the vicinity of the researcher's role. Whilst in this way one of the issues identified in the first cycle was responded to, further configuration/alienation of the level of questions in such a test with the level of questions of final exam is recommended. Moreover, performing this basic cluster assessment was important in order to ensure that the issues identified in the first cycle were also relevant to the second cycle students. Using these issues, the next section relates to the second stage of the second cycle in the SCOR methodology and provides the operation/action planning and design.

4.3.2. Stage 2: Operation/Action Planning and Design

Table 51 shows the data/information sources as well as the planning and design methods for this stage.

Second Cycle: Operation/Action Planning and Design Stage	
Data/Information Sources	Performance results of Previous years, Attendance results, the collective of issues and categories identified in the first stage (first cycle) presented in Table 30, as well as interpretations of ethnographic observations in the first stage of second cycle.
Planning and Design Methods	**Quantitative analysis of Exam Performance (Beer, 1972)** • Finding the Actuality of system in terms of KPI of Exam Success • Finding the Capability of system in terms of KPI Exam Success • Finding the Potentiality of system in terms of KPI of Exam Success **Considerations for Social Capital Dimensions (Nahapiet and Ghoshal, 1998)** • Relating to cognitive, relational and structural capital through students attendance **Domains of Viable Knowledge (Achterbergh and Vriens, 2002)** • Relating to and interpreting the 31 domains of viable knowledge through creating a method note

Table 51: Methods for Planning and Designing in Operation/Action Planning and Design Stage – 2nd cycle

4.3.2.1. Process

Reflecting on the diagnosis and detailed analysis of the first stage in both the first and second cycle of the SCOR methodology, the researcher designed the systemic solution from 5th to 15th January 2017. The plan of actions/operation was discussed with the module leader, as well as the teaching and tutorial team in a meeting on 26th January 2017. The details of how the systemic solution was designed are presented next.

4.3.2.1.1. Viable System Model: Planning for Better Performance

At this stage of the second cycle, the concept of performance measurement in the viable system model was used, similar to the first cycle. For this purpose, the researcher referred again to the notions of actuality, capability and potentiality of the system. Understanding that learning is emergent, the aim, however, was not to quantify the processes of teaching/learning.

4.3.2.1.1.1. Finding System's Actuality, Capability and Potentiality – Exam Performance

In order to figure out the system's actuality in terms of students' success rates, the researcher analysed Table 47 (Section 4.2.5), based on their failure rates in the previous years. It was evident that the system's actuality in terms of students' success rate can be explained from two perspectives. First, the system's actuality for student success rates based on the tutorials added to the structure of APS-Maths stood at 78%. Second, when the exam results that emerged from the systemic solution were taken into consideration, the actuality of student success rates was 87% success in the exam. Since the aim was to examine and observe the effect of the systemic solution in terms of the maths knowledge network in the two cycles of operational research, the researcher focused on the first perspective. Therefore, for the second cycle the actuality of the system for the KPI of student success rate was considered as 78% success in exam. In order to figure out the capability of the system for this KPI, the researcher used Table 47 again. Such analysis showed that the capability of the system in terms of students' success rate was 83.75%. With regard to potentiality, since the module leader decided to continue providing the tutorials as part of the teaching structure in the second cycle, the potentiality of the system in terms of student success rate remained unchanged at 90%. Using actuality, capability and potentiality for this KPI, it was possible to measure the productivity, latency and performance of the system, relevant to student success rate.

Productivity = Actuality/Capability = 73.85/83.75 = 0.93
Latency = Capability/Potentiality = 83.75/90 = 0.93
Performance = Productivity*Latency = 0.93*0.93 = 0.86 = 86%

In other words, it was excepted to observe 86% students' success in the exam for the academic year 2016-17. Whilst the actuality, capability and potentiality of the system in terms of students' success rate were figured out and declared, the researcher considered finding a practical way towards managing the dimensions of students' social capital in the system. The following section explores these dimensions.

4.3.2.1.2. Considerations for Managing Dimensions of Social Capital

As part of planning for action research, the researcher referred to the students' rates of access to learning/developmental activities through their attendance results in the first semester. Similar to the first cycle, the effective management of social capital could then be achieved through mixing students with different maths skills (i.e. mixing different kinds of cognitive capital) by considering how the patterns of their access to learning/development opportunities have emerged (their relational capital), and by creating the conditions that make learning more likely (structural capital). For this purpose, the researcher first analysed the data in Table 50 to shed light on the ratios of access to developmental workshops of maths learning. Table 52 shows these ratios.

Base: Attending at least 5 maths Workshops	Ratio	Scenario
Very Strong Students (Attending) to Not-Very-Strong Students (Attending)	1:4	1
Very Strong Students (Attending) to Not-Very-Strong Students (Total of Attending and Not-Attending)	1:11	2
Very Strong Students (Attending and Not-Attending) to Not-Very-Strong Students (Attending)	1:2	3
Very Strong Students (Attending and Not-Attending) to Not-Very-Strong Students (Attending and Not-Attending)	1:6	4

Table 52: Ratios of Access to Maths Sessions – 2nd cycle

Acknowledging the complexities involved in the case of students' attendance, similar to the first cycle, the researcher assessed the likelihood of the worst case, in which every highly-skilled student would choose to attend just five sessions (those five sessions that no low-skilled student attended). Referring to the data, among those who attended at least 5 sessions, only 33 out of 356 (9.3%) students attended just 5 workshops (1.4% highly-skilled and 7.9% lower-skilled students). Since the researcher did not have access to the details of sessional attendance per student, this 9.3% advocated that from those who attended at least 5 sessions, 90.7% of them attended more than 5 sessions and this dramatically increased the likelihood of highly-skilled and low-skilled students being in the same session. Hence, the ratio in the first scenario is very reliable.

Comparing Table 34 and Table 52, it is evident that the ratios of the two research cycles differed in the second and fourth scenarios. Since 100% attendance very rarely happens in reality, the fourth scenario would not be realistic. The second scenario shows that if all low-skilled students in the APS-Maths module were attending at least five workshops, then there was only 1 highly-skilled student available per 11 of them in order to create a team with a skills-mix. Yet, based on one of the findings in the first research cycle (see Section 4.2.3.1.3.2.3), teams comprising more than five members could not effectively help each other. This shows that the situation could be worsened in the second cycle if all low-skilled students decide to attend at least five workshops, whilst only a few highly-skilled students would be attending. The ratio of the first scenario was more likely to emerge again in the second semester of APS, since it was only relying on those who attended at least five workshops in the first semester. Therefore, the researcher aimed to group students into teams of five, similar to the first research cycle. Each team of five comprised one highly-skilled student and four low-skilled students in order to achieve the skills-mix required in collaborative knowledge sharing and experiential learning.

4.3.2.1.3. Viable System Model: Domains of Viable Knowledge

Similar to the first cycle, the structure of the desired knowledge network for the extra maths sessions was shaped by Achterbergh and Vriens' (2002) 31 domains of viable knowledge. Since the exact same interpretations of these domains were used in the second cycle, the researcher avoids rewriting them in this section (see Section 4.2.2.1.2).

With reference to Section 4.2.5 (the reflection and learning from the first cycle), the conclusion was to carry out the second cycle of the systemic solution in the extra maths sessions through action research. This meant creating a maths knowledge network, in order to develop students' maths skills and to improve their performance. Having identified the ratio in the teams and declaring the desired structure, next was the implementation of operational plan 3, which was the extra maths sessions/maths knowledge network (for operational plan 3, see Section 4.2.1.3).

4.3.3. Stage 3: Implementing the Actions/Operations

In the implementation stage of the SCOR methodology, the researcher referred to operational plan 3, as discussed in stage 2 of the second cycle (Section 4.3.2).

Second Cycle: Actions/Operations Implementation Stage	

Operational Plan Three	**Creating a knowledge network in extra maths sessions**
	• **Activities of Week 1:**
	  • Teams assembly based on maths knowledge level
	  • Defining Goals and Identity
	  • Getting to know the method of collaborative knowledge sharing and Introducing the viable system model
	  • Justification on the expected benefits for students with different maths levels
	  • Defining and agreeing on underlying rules for the sessions
	• **Activities of Week 2 and Onwards:**
	  • Teams assembly based on maths knowledge level
	  • Facilitating maths question solving practices in teams through collaborative knowledge sharing, according to 31 domains of viable knowledge (note on method)
	  • Gathering the individuals' and teams' feedback forms
	  • Weekly reflection on the feedback forms and monitoring the maths skills development
	  • Weekly Preparation/Printing the learning and practice materials based on the feedback forms

Table 53: Implanting Actions/Operations, Operational Plan 3 – 2nd cycle

4.3.3.1. Process

The researcher reflected on the design of the actions/operations. The plans of actions were implemented from 15th February until 18th May 2017. To carry out this study for the second cycle, the system in focus was the extra maths sessions and the primary activity for the system was defined as knowledge sharing and collaborative experiential learning in teams.

4.3.3.1.1. Implementing Operational Plan 3/Maths Knowledge Network

Since the researcher was involved in both the workshops and tutorials of APS-Maths, it was possible to promote the extra maths sessions to students of each stream throughout the first semester. They asked if they could register their names and be informed of the first session. 42 students registered to attend at this stage. Checking their names against their formative quick test results, it was evident that both highly-skilled and low-skilled students were willing to attend the extra maths sessions. Their enthusiasm came to light when six students from different workshops approached the tutor and asked when the extra sessions would start. The researcher decided to arrange a preliminary gathering. This session was an introduction to hear students' opinions about their experiences and their perceptions of maths prior to implementing the first week's activities. Hence, the researcher sent an email to these 42 students on 19th November inviting them to attend the gathering on 24th November 2016. Attending this session, the researcher started informally asking how they were, how their day was, and how their studies were going on. Greeting respectively, they expressed their stress and anxiety about APS-Maths. One of the students said:

> *"I was not in a good high school. Different supply teachers or teaching assistants taught in our maths lessons and that was not helping at all" (Student Comment, Preliminary Session).*

There were six other students nodding that this was also the case for them. Five additional students mentioned that they had heard from the last year's students about extra maths sessions and decided to attend. The researcher talked about the achievements of the previous year's students as part of her PhD action research. She then informed students that the extra maths sessions would be carried out in the second semester. She ensured the learners that they would enjoy their time of learning together and this would reduce their stress to a great level and increase their confidence. In addition, the researcher invited students to join the APS-Math Facebook group (staged the year before) to be informed promptly of the schedule of the first week's sessions. They appeared happy with this arrangement. On 12th February 2017, the schedule of the first week of extra maths sessions was posted on the Facebook group.

4.3.3.1.1.1. Implementing the First Week's Activities

The first week of implementation comprised two sessions (15th and 20th February 2017). Students signed the consent forms. The banquet-sitting layout and team assembly ratio of 1:4 were applied in these sessions. Welcoming students, a brief recall of the gathering of 24th November 2016 was discussed, followed by a short debate on issues involved in APS-Maths. The researcher then handed out a sample of the maths questions and asked the students to reflect on the level of the questions, and to devise a goal for their teams in terms of how they would work to reach such a level of maths skills. Pictures 8 and 9 illustrate their efforts.

Picture 8: Teams discussions for their team goals - 2nd cycle

Picture 9: A team reflection on the sample - 2nd cycle

The researcher then facilitated a dialogue to reach an agreement on the goal and the identity of the extra maths sessions, similar to the first research cycle. In addition, after each student had been handed the method of knowledge sharing (see Appendix 2), they reflected, asked questions and discussed the method in relation to achieving their goals. After these activities, the researcher started to introduce the basics of the viable system model with a discussion on how it relates to the method of knowledge sharing (see Appendix 3). Students also learned how this method was expected to benefit them through a motivation note (see Appendix 4). Following this, the researcher referred to the differences in the learning processes found through ethnography in different streams of students and asked them if they were interested in defining their own ground rules/norms – something that they all stated they would be committed to. Here, they started to appreciate the skills-mix more. Table 54 reveals students' agreements.

Concepts	Agreed statements	Representing
The teams' goal	"To assist each other in the team for learning how to solve all maths questions."	System 1' objectives
The class goal and identity	"To form and maintain a network for practicing and learning math together to pass the math exam."	System 5's function
Ground rules/Norms	• To follow BSUKU's code of student conducts • To make sure all of the learning topics are discussed and practiced before the exam deadline • To practice on the maths questions through teamwork • To keep up the friendly manners in knowledge sharing and learning together • To keep mobile phones on silent mode • Soft drinks, biscuits and snacks are permitted	System 5's ethos and governance

Table 54: Teams' goal, Identity & Class goal and Ground rules – 2nd cycle

4.3.3.1.1.2. Implementing the Activities of the Second Week and onwards

The activities of the second week and onwards were from 21st February to 16th May 2017. A total of 49 students attended 15 extra maths sessions for collaborative knowledge sharing and experiential learning (18 session in total, including the first week's sessions). The process of scheduling the extra maths sessions in the second cycle turned dynamic. In each session, the researcher planned for the date and timing of the next session. Information about the next session was then put on the Facebook group to remind students. Since the researcher was involved in the maths workshops and tutorials, she was informing other students about extra maths sessions accordingly.

The sitting style and ratio of 1:4 were the same as the session in the first week. The choice of topics and practice questions was based on discussion with students in each session. Questions were then printed and made ready for students to practise in the next session. Students understood the method of collaborative learning/practising in the first week of the solution, and therefore they easily engaged with solving maths questions in the second week using the method note. Picture 10 shows the collaborative learning and practice of experiential learning in two teams. The two teams were sitting beside each other and could ask each other's members if they could not reach a conclusion in their own team. This enabled the process of knowledge brokerage.

Picture 10: Teams Discussions and Processes of Experiential Learning – 2nd cycle

They also allocated 10 minutes at the end of each session to reflect on their experiential learning, to brainstorm on the strategies for improvement in the teams, and then to collectively discuss in the class and approve an idea that sounded more beneficial to all. They recorded their strategies in each session through filling in individual and team feedback forms (see Picture 11).

Picture 11: A Team Discusses Filling in the Feedback Forms – 2nd cycle

4.3.3.1.1.2.1. First Type of Feedback Loop: More Experiential Learning

The researcher understood the type of feedback loop based on what students decided for their performance improvement. This was highlighted on their feedback forms, both individually and in the teams. They recognised the need for more questions and more collaborative practice sessions in order to fully understand the maths concepts and comprehend how to solve the questions. They also suggested what resources could be used to select more questions. The researcher then facilitated the organisation/printing of those questions. Hence, their strategy was the continuous experiential learning cycle, up to the point where everyone in the team could feel confident and become skilful on each topic. Reflectively, this strategy was a mechanism for system 3 to monitor and regulate the activities of system 1 in their skills development and performance improvement. The tactical planning in system 2 was also clarified based on this strategy.

4.3.3.1.1.2.2. Second Type of Feedback Loop: Managing Teams' Complexities

Another key feedback loop referred to teams' complexities. With the learning from the first cycle, the researcher was cautious about the number of students in each team. In two of the sessions where the number of present students was not a multiple of five, it happened that one team was left with only three students. Based on the feedback forms from both sessions, students in the team of three members strategised and planned to be in a team of more students next time. Although it was expected that this situation would be in favour of low-skilled students (more time for obtaining support from the highly-skilled students in their team), this instance appeared to show that more viewpoints in the team discussions contributed to a better process of collaborative experiential learning. Notably, team complexities at the implementation stage of each of the first and second cycles were different. In the two instances in the first cycle, it was the highly-skilled students who reported frustration with excessive regulatory tasks of monitoring, checking and discussions in their bigger teams (Section 4.2.3.1.3.2.3). In the two instances in the second cycle, it was the low-skilled students who reported the demand for more students in their team in order to have more perspectives in their team's discussions.

Another observation of team complexity management in the second cycle related to a dyslexic student (D53), who was slower than his/her teammates. The researcher observed that the team self-organised itself in order to provide more discussion, more details and to be more patient to accommodate their teammate. This practice clearly paved the way for the dyslexic student to develop his/her skills effectively to an extent that later she could monitor and check her teammates' work and help them. For example, when solving a quadratic equation in the team appeared to be a complex task to understand, he/she confidently offered to explain it in detail and checked how other peers had proceeded in their process of solving the questions. It was apparent that the team's self-organisation empowered him/her to a great extent, so much so that he/she could play a proactive role in her team and the class.

4.3.3.1.1.2.3. Third Type of Feedback Loop: Access to an Online Platform

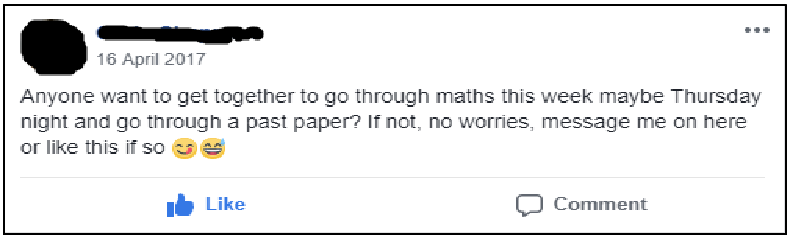
From the beginning, students joined the APS-Maths Facebook group (staged the year before) in order to be notified of extra maths sessions on their mobiles. While the researcher could create a new Facebook group for these students, it was decided that joining the same Facebook group would create a bigger supportive learning network for students. Although students could use this platform to solve a question together online (by posting it in the group and proceeding with the process of solving it in the comments, similar to the approach which students of the year before adopted), they used this online platform more for coordination, announcement and organisation of the extra maths sessions. In addition, the emerging events, which will be discussed next, were organised and arranged on this Facebook group. Hence, for the second cycle students, the Facebook group was a pivotal mechanism of system 2.

4.3.3.1.1.3. System's Evolutions: Emerging Phenomenon

With the progress in the skills development for students, the following events emerged.

4.3.3.1.1.3.1. Emerging Event: Development of Knowledge Leaders

Since students demanded more maths sessions, after session 8, one of the highly-skilled students (A6) asked the researcher if he/she could facilitate and lead a maths session. There was no objection to this request. Therefore, he/she used the Facebook group to ask students whether they wished to get together for an extra maths event (see a screenshot of his/her initiative in Picture 12).



Picture 12: Initiative for a Session by a Highly-Skilled Student – 2nd cycle

Said session (session 9) was finalised for 20th April 2017, and facilitated by the student using the same method of collaborative experiential learning/practising. After this event, the researcher facilitated the next extra maths session. The same student asked again to facilitate/lead another session. Upon agreement, that student's next session (session 11) was scheduled for 27th April 2017 (see a screenshot of his/her initiative in Picture 13).

Picture 13: Invitation for Another Session by a Highly-Skilled student – 2nd cycle

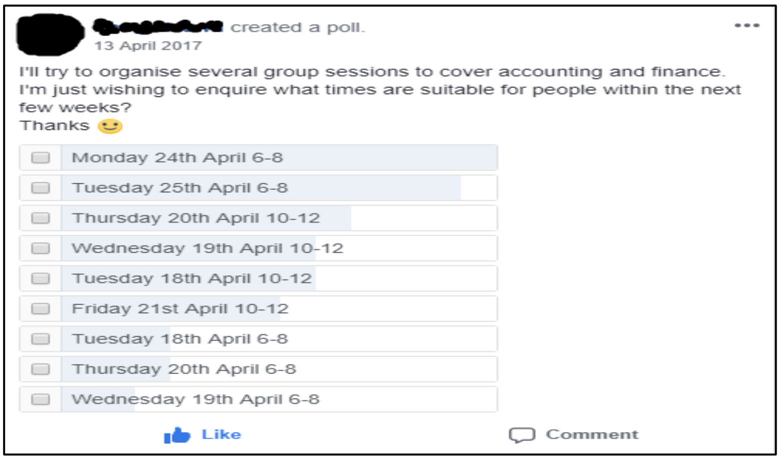
This session was also performed in a way similar to a normal extra maths session facilitated by the researcher. Students worked in teams, discussed and debated each other's work, and strategised with a view to achieving better performance in the session after. The researcher observed these two sessions and it was evident that this highly-skilled student turned into a knowledge leader who could manage and guide the whole class of students for their collective knowledge sharing and collaborative learning in their teams. After these student-led sessions, the researcher continued the facilitation of the rest of the extra maths sessions.

Further, the Facebook platform created a collaborative environment between the students involved in the first cycle (2015-16) and those involved in the second cycle (2016-17) in such a way that two of the students from the first cycle offered to lead a maths session for the students of the second cycle. One of them was the same highly-skilled student who led two sessions the previous year. The other was another student who attended one of the extra maths sessions and helped the researcher in facilitating the team processes for the experiential learning/practising (Picture 14). This was also a new type of feedback loop. The insights from the collaborative experiential learning in the first cycle could be fed back by a student to the collective knowledge sharing and collaborative experiential learning in the second cycle.


Picture 14: Facilitating of Collaborative Learning by an APS-Maths Student from the Year Before – 2nd cycle

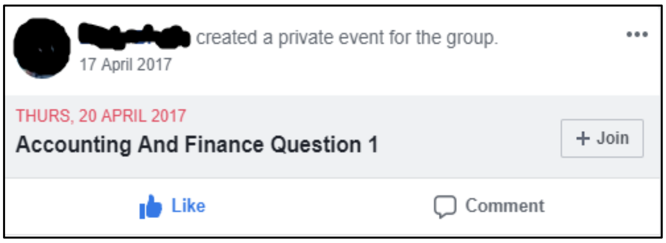
4.3.3.1.1.3.2. Emerging Event: Ability of the System for Self-Reproduction

After session 8, students reached an understanding that the method used in their extra maths sessions served the purpose and identity. They decided that they could also create some collaborative experiential learning/practice sessions for their module of accounting and finance. They asked if the researcher would facilitate such sessions. Although this was not possible for the researcher, one of the students (C53) took the initiative, announced the aforementioned organisation of learning events on the Facebook group, and then created/facilitated the events. Picture 15 shows a screenshot of said coordination. Students used the same method of collaborative learning and experiential practice in those sessions.



Picture 15: Arrangement for System's Self-Reproduction – 2nd cycle

The first of the series of the system's self-reproduction was created for 20th April 2017 (Picture 16).



Picture 16: Initiative of a Self-Reproduction Event – 2nd cycle

Reflecting on the events which emerged in the first and second cycles, the researcher observed that students in both cycles were proactive in self-organising relevant activities towards the identity and purpose of their own learning system. The researcher recognised the importance of providing the opportunities for students to lead a session. With the learning and insights gained from managing the first cycle, the researcher became more facilitative towards students' collaborative skills development and performance improvement.

4.3.4. Stage 4: Evaluation and Assessment

In this section, the researcher illustrates and discusses the evaluation of operational plan 3/the maths knowledge network for the second cycle.

Second Cycle: **Evaluation and Assessment Stage**	

Assessment and findings of Operational Plan Three	**Impact of creating a knowledge network in extra maths sessions**
	• **Analysis of maths exam success performance**
	  • Quantitative comparison and Statistical graphic technique
	
	• **Assessing the change in maths skills level**
	  • Correlation Analysis
	  • Regression Analysis
	  • Analysis of fluctuations in the dynamic process of skills and confidence development
	  • Analysis of fluctuations in satisfactions on support received
	
	• **Assessing the change in maths knowledge network (using UCINET)**
	  • Graphic technique of SNA
	  • Quantitative SNA
	    • Network level measures
	      iv. Network Density
	      v. Network Cohesion
	      vi. Average distance in the network
	    • Individual level measures
	      iv. Degree centrality
	      v. Eigenvector closeness
	      vi. Flow Betweenness
	
	• **Results of assessing developments in strategies**
	  • Strategy analysis through reflection on relevant theories

Table 55: Evaluation and Assessment of Implemented Plan – 2nd cycle

4.3.4.1. Results of Assessing Maths Exam Performance

Figure 46 shows the overall APS-Maths performance, whilst Figure 47 and Figure 48 illustrate the performance of those under the systemic solution (maths knowledge network) and the performance of the rest of the students, respectively.

Evidently, there was a major increase in the pass rate for those who participated in the maths knowledge network for their maths skills development. The next achievement of the systemic solution was 0% rate of no-show.

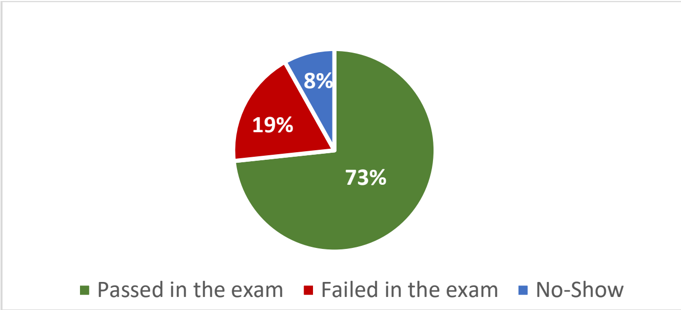


Figure 46: Overall APS-Maths Performance – 2nd cycle

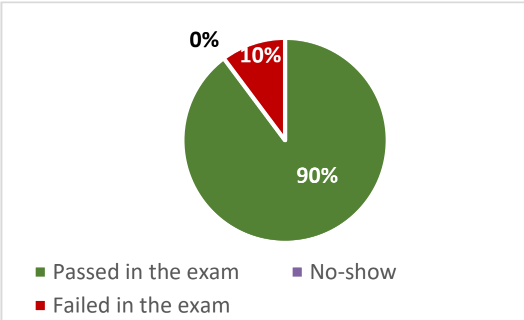


Figure 47: APS-Maths Performance, Involved in Maths Knowledge Network (OP3) – 2nd cycle

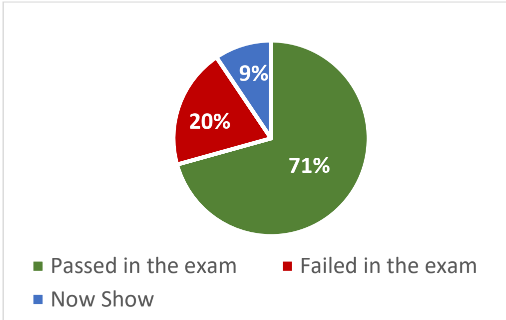


Figure 48: APS-Maths Performance, Not Involved in Maths Knowledge Network (OP3) – 2nd cycle

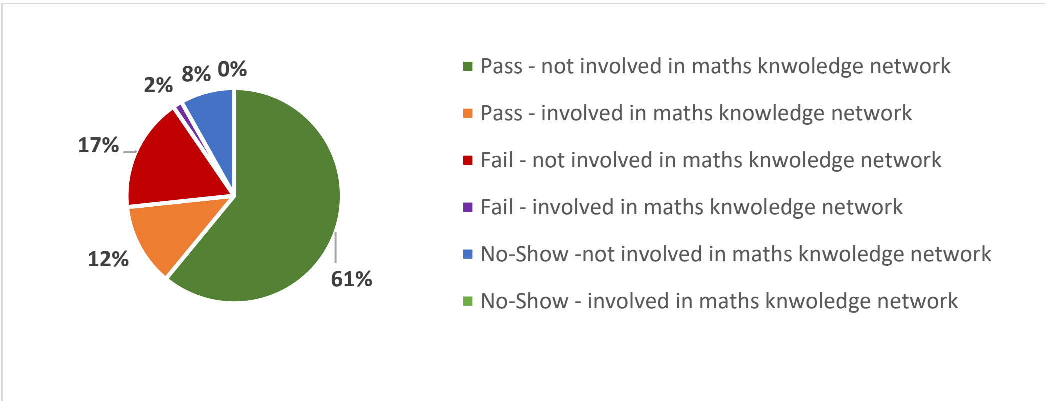


Figure 49: APS-Maths Proportional Exam Performance – 2nd cycle

Figure 49 shows a proportional perspective on APS-Maths final exam performance for both those involved in the maths knowledge network and those not involved. It also shows that those involved in the maths knowledge network (OP3) exhibited 2% fail out of the 19% fail in the whole APS-Maths module. In addition, whilst all students involved in the maths knowledge network (OP3) attended their APS-Maths final exam, there was a 9% no-show in the final exam for the rest of the students (Figure 47 and Figure 48). This is evidence of increased motivation for final exam performance in terms of attending. The researcher relates to this motivation as emergent from confidence that students gained in the process of skills development under the systemic solution.

Similar to the first cycle, the design of this action research happened to have pre-test and post-test features which created some opportunities to consider and discuss certain results. The researcher created four exam mark bands and used a paired two samples t-test to determine the means for each band (see Appendix 15 and Appendix 16). Effect size of each t-test was then calculated, which supported the provision of some indicative inferences in this research. Chart 7 shows the mean differences between the formative test and the final exam per mark band for those involved in the maths knowledge network (OP 3) and those not involved (all p-values were less than 0.05).

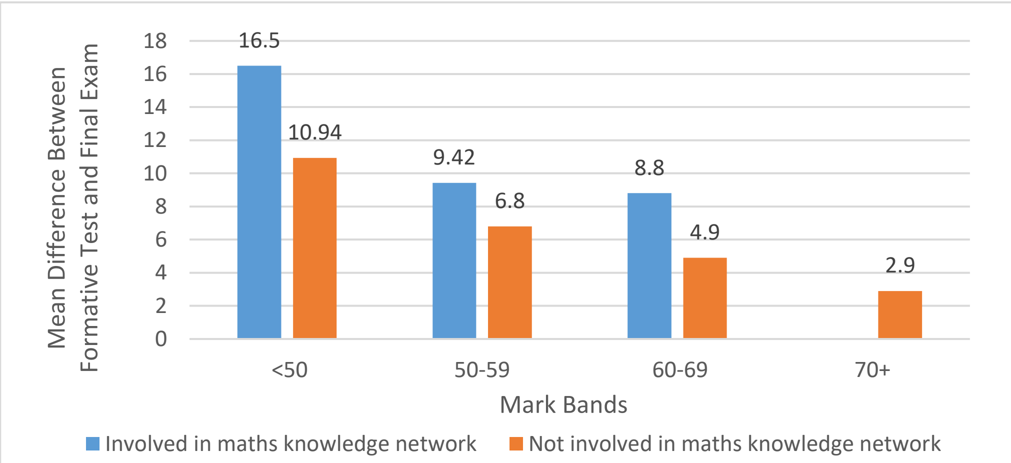


Chart 7: Mean Differences per Mark Band – 2nd cycle

Table 56 shows the size effect of the mean difference for each mark band.

Bands of Mark	Effect size – In maths knowledge network	Effect size - not involved in maths knowledge network
<50	2.2	1.3
50-59	2.7	2.3
60-69	3.3	1.6
70+		0.7

Table 56: Effect Size of Mean Differences per Mark Band

Chart 7 shows that the average increase of marks for those involved in the maths knowledge network was greater than the average increase for those who were not involved in the maths knowledge network in each of the mark bands. The level of increase was also impressive. In addition, it is interesting to observe that the average increase for those in band mark <50 was higher than in any other band. This means that the approach adopted in the knowledge network has been more effective for those who were initially low-skilled. Comparing the results in cycle 1 and cycle 2, it appears that when students took the formative test at the very beginning of the semester, the situation was more beneficial for low-skilled students (those in mark band <50, see Chart 6 and Chart 7). They could self-organise their learning and perform better. Further, according to Table 56, the effect sizes of mean difference in each mark band for those who participated in the maths knowledge network were greater than those for the students who did not participate. The size effect is a means for quantifying the difference between the two groups. It measures the strength of an intervention. The higher the effect size, the stronger the relationship between an intervention and an outcome. The effect size here in this research conveys the estimated magnitude of a possible relationship. Effect size, however, makes no statement about the true relationship.

4.3.4.2. Results of Assessing Change in Maths Skills Level

Table 57 presents the results of correlation analysis on data taken from all sessions.

	Confidence rate - start	*Skills rate - start*	*Confidence rate - end*	*Skills rate - end*	*How happy the team is with support received from each other*	*How happy the team is with support received from Facilitator*
Confidence rate - start	1.000000000					
Skills rate - start	0.922913710	1.000000000				
Confidence rate - end	0.896845456	0.858870665	1.000000000			
Skills rate - end	0.848832910	0.866213839	0.916151696	1.000000000		
How happy the team is with support received from each other	0.333362917	0.303823730	0.330490580	0.346820584	1.000000000	
How happy the team is with support received from Facilitator	0.342816458	0.329832921	0.337934392	0.378153007	0.726920624	1.000000000

SUMMARY OUTPUT FOR: SKILLS RATE - END	
Regression Statistics	
Multiple R	0.930974416
R Square	0.866713363
Adjusted R Square	0.864563579
Standard Error	0.567280926
Observations	190

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	389.2227247	129.7409082	403.1629107	4.10099E-81
Residual	186	59.85622262	0.321807649		
Total	189	449.0789474			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.585538242	0.19351145	3.02585837	0.002830381	0.203778831	0.967297653
Confidence rate - start	-0.176168743	0.081192017	-2.169779123	0.031291656	-0.336344364	-0.015993123
Skills rate - start	0.392755543	0.06843586	5.739031329	3.80928E-08	0.257745271	0.527765814
Confidence rate - end	0.752569711	0.063729169	11.80887377	2.2456E-24	0.6268448	0.878294623

Table 57: Correlation and Regression Analyses for Skills Rate – end in APS-Maths OP3 (Maths Knowledge Network) – 2nd cycle

Referring to Table 57, it is evident that skills and confidence at the end of the sessions were strongly associated with skills and confidence at the start of each session (all correlation coefficient values were more than +0.84). Maths skills developed at the end of each session were related to a combination of confidence at the start (r=-0.17), skills at the start (r=+0.39) and confidence at the end of each session (r=0.75). All p-values were less than 0.05 and the coefficient of determination (r-square) was 0.86. The slight fear and anxiety about maths that can lead to loss of confidence was observed in the negative week correlation between confidence rate at the start and the skills developed at the end of the sessions. Figure 50 depicts the fluctuations in the process of maths skills development. It appears that skills and confidence development accelerated after progressing half way through sessions.

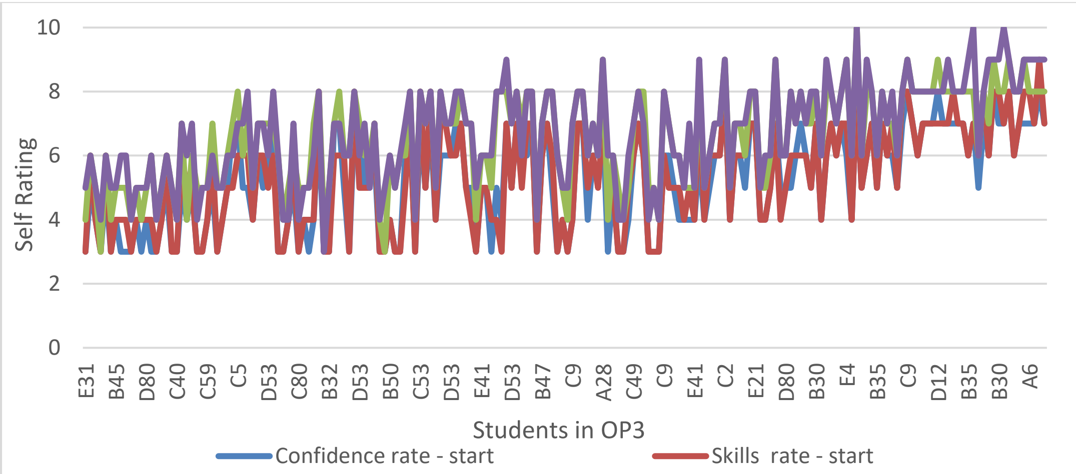


Figure 50: Fluctuations in the Process of Skills and Confidence Development in OP3 (Maths Knowledge Network) - 2nd Cycle

Further, Table 58 shows regression analysis for satisfaction with facilitator's support.

SUMMARY OUTPUT FOR: HOW HAPPY THE TEAM IS WITH SUPPORT RECEIVED FROM FACILITATOR						
Regression Statistics						
Multiple R	0.726920624					
R Square	0.528413593					
Adjusted R Square	0.525905155					
Standard Error	0.658706172					
Observations	190					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	91.40164595	91.40164595	210.6544081	1.64263E-32	
Residual	188	81.57203826	0.433893821			
Total	189	172.9736842				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	2.727581242	0.33585962	8.121194333	5.95177E-14	2.0650435	3.390118984
How happy the team is with support recived from each other	0.668192102	0.046037959	14.51393841	1.64263E-32	0.577374738	0.759009466

Table 58: Regression Analysis for Satisfaction with Facilitator's Support in OP3 (Maths Knowledge Network) – 2nd cycle

As Table 58 shows, students' satisfaction with the facilitator's support was associated with their satisfaction with support received from their peers (with r =+73). Based on regression analysis, since r-square was 0.53, therefore 53% of the data on how happy teams are with the facilitator's support was explained by the data on how happy teams are with the peer support in their teams. This is a positively moderate strength correlation. It might refer to the certain part of the facilitator's role for organising the team structures so that they could support each other. Figure 51 shows the fluctuations in the satisfaction with the support received from the facilitator and from peers.

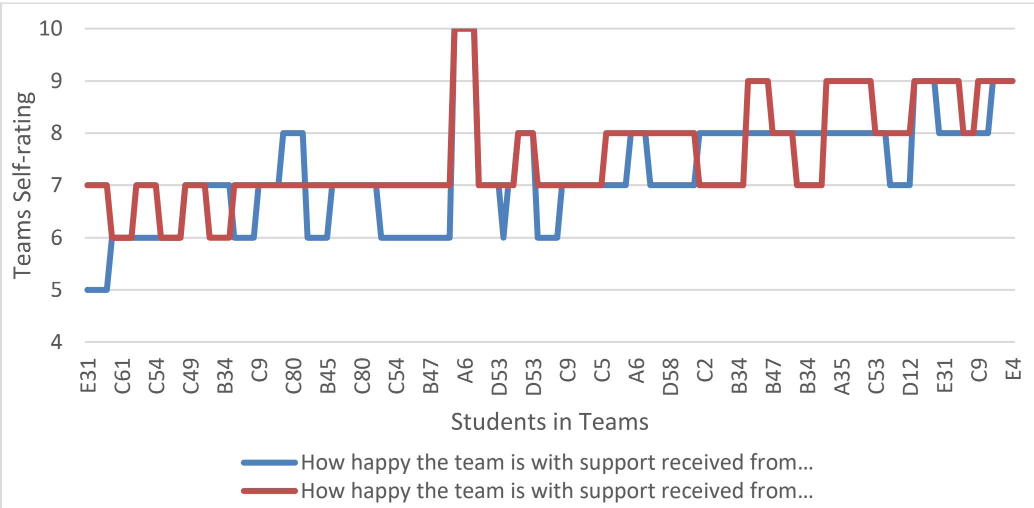


Figure 51: Fluctuations in Satisfactions – Receiving Support from Facilitator and Peers in OP3 (Maths Knowledge Network) – 2nd cycle

The next section further illustrates help seeking cases in the teams and across the teams along the course of extra maths sessions through a basic social network analysis.

4.3.4.3. Results of Assessing Change in Maths Knowledge Network (SNA)

A basic social network analysis was performed to uncover the changes in the maths knowledge network after the systemic solution. Figure 52 illustrates the underlying structure of the network.

Teams are shown in dark blue squares and individual students are the red circles. Evidently, knowledge sharing and collaborative experiential learning/practice occurred within teams and expanded further across teams. It is important to note that the 39 teams were arranged throughout the extra maths sessions. Hence, the team numbers also show the order of team creations through time.

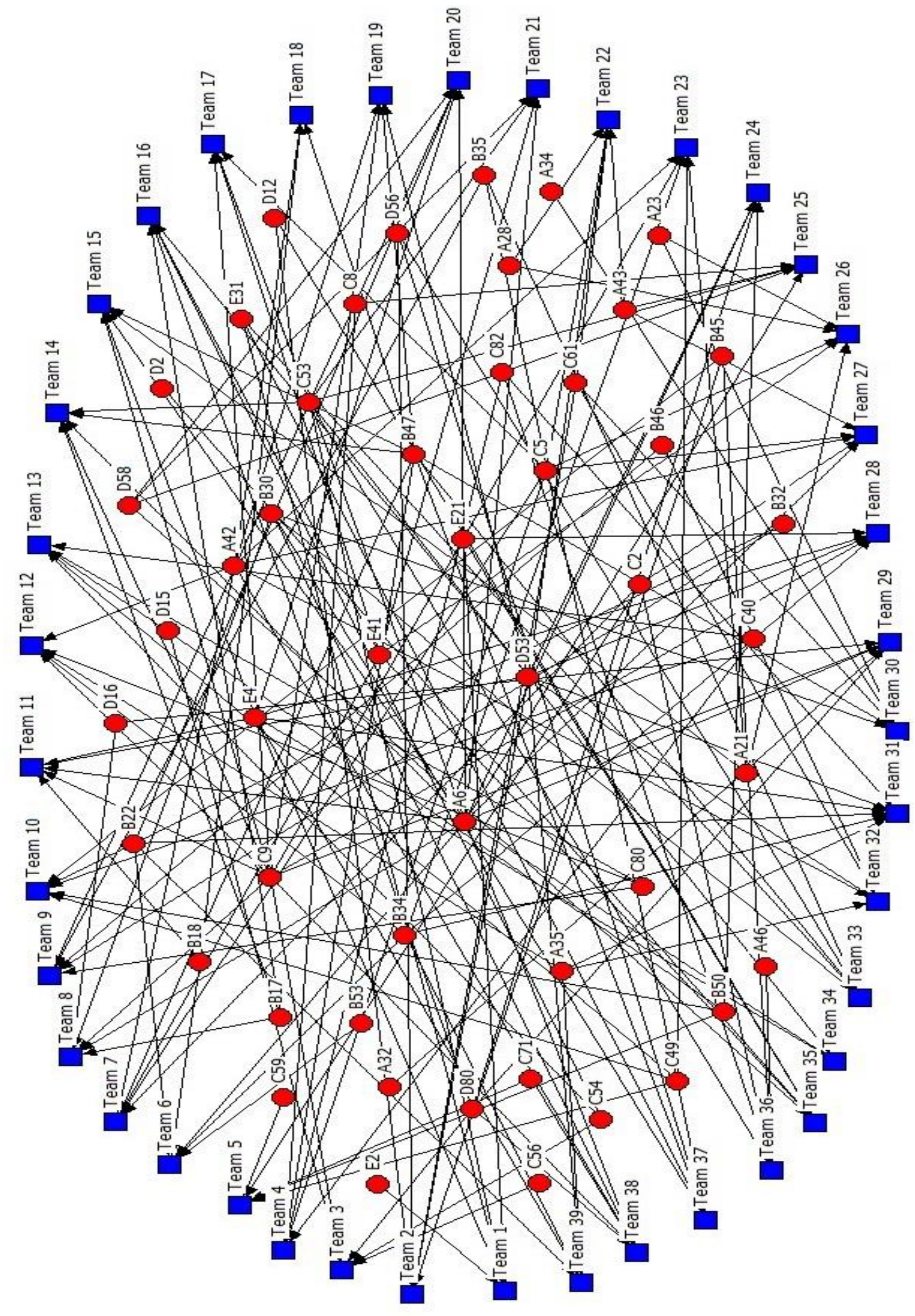


Figure 52: Students Attending Different Teams Throughout the OP3 (Maths Knowledge Network) – 2nd cycle

Figure 53 illustrates which teams are the key components of the network in connecting students together, without which some students may be disconnected from the network. In this graph, all normal components, whether teams or individuals, are represented in red colour. Those in blue colour show the cut-points. Eight teams were in critical positions to keep everyone connected throughout the sessions.

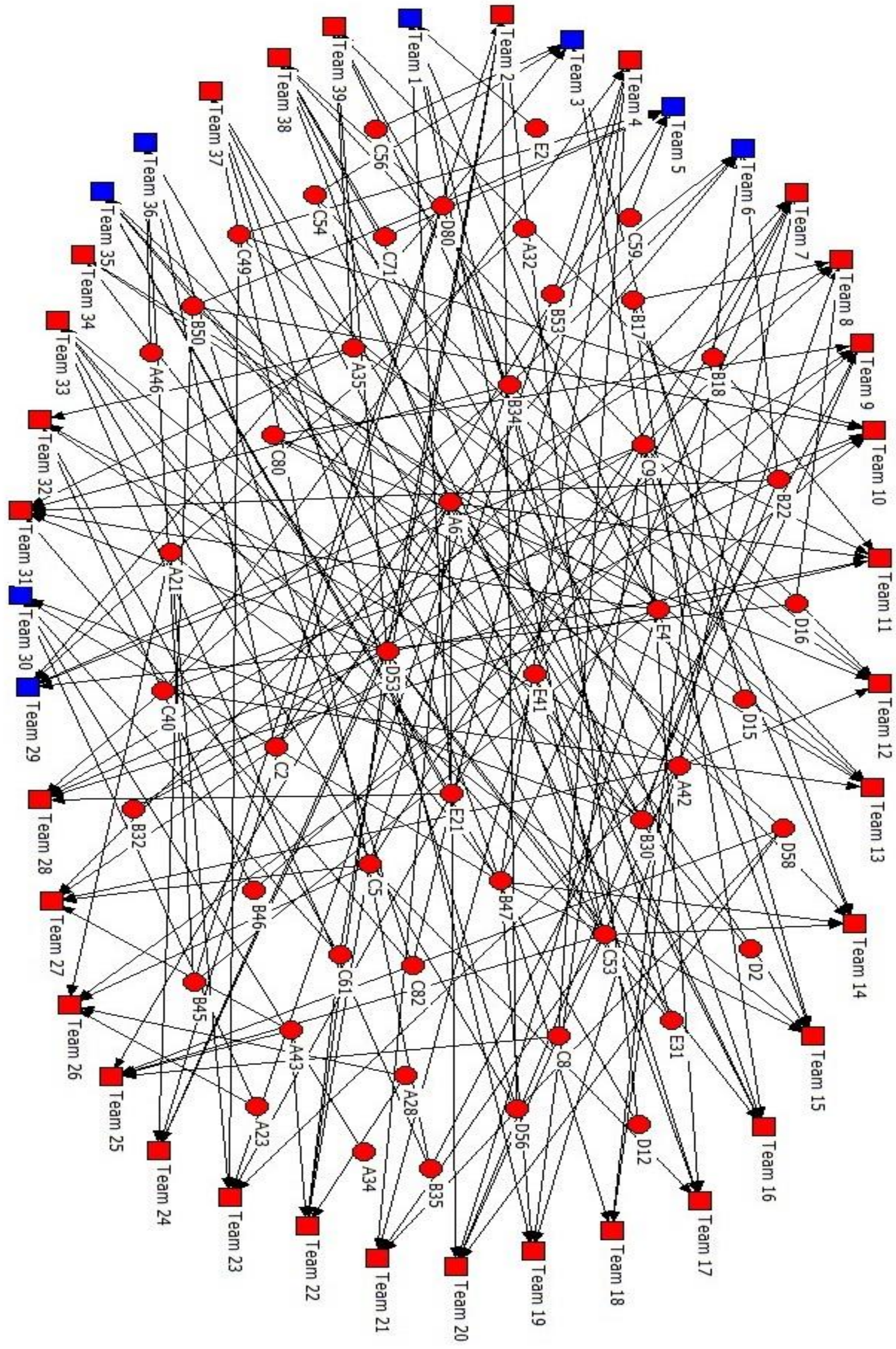


Figure 53: Blocks and Cut-Points in OP3 (Maths Knowledge Sharing Network) – 2nd cycle

In addition, the level of connectivity among students is recognised through their ties. Figure 54 shows the total ties which emerged for knowledge sharing and collaborative experiential learning/practice.

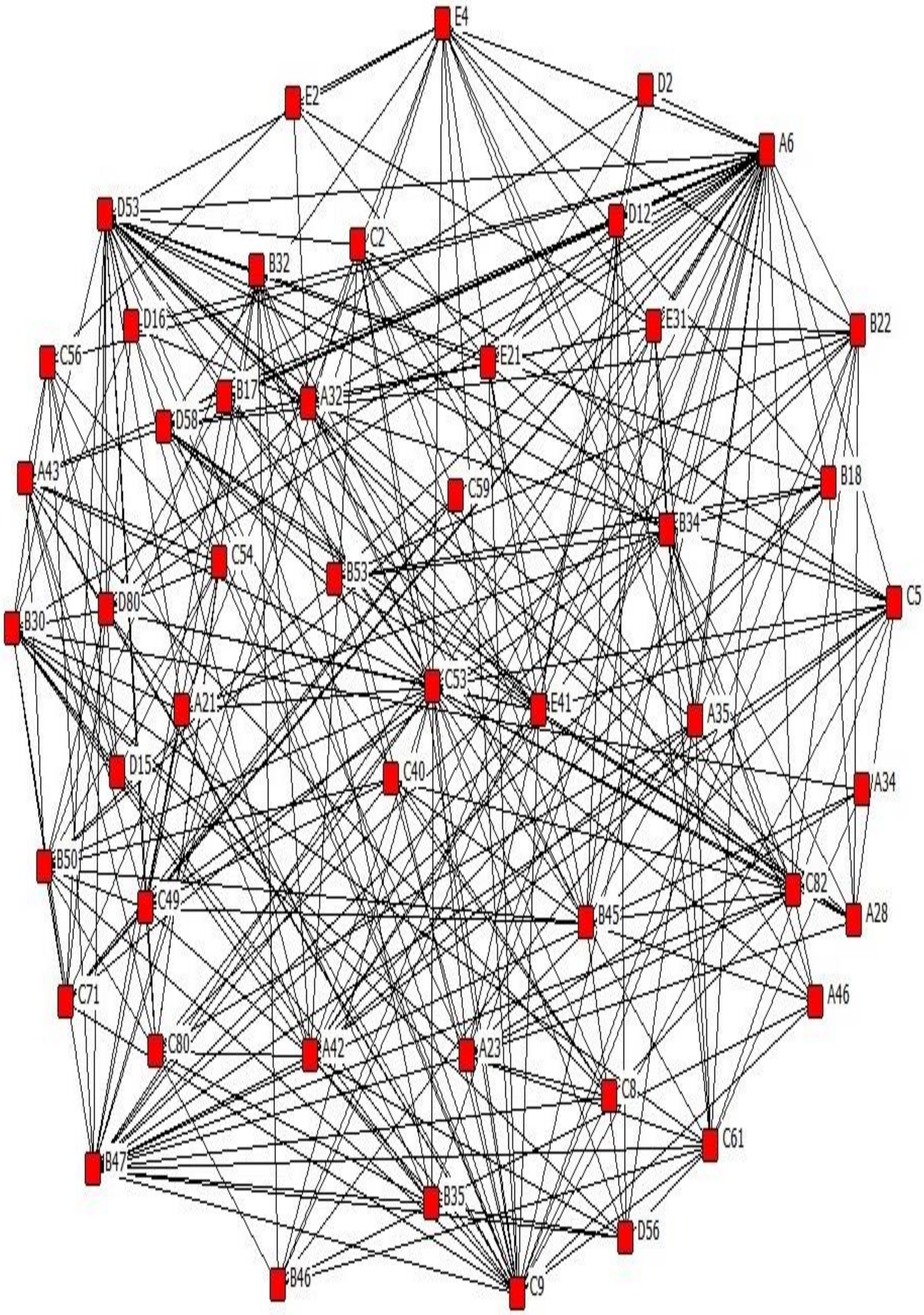


Figure 54: Total Ties which Emerged for Knowledge Sharing and Collaborative Learning/Practice, OP3 (Maths Knowledge Network) – 2nd cycle

Figure 55 illustrates the strength of students' ties in the maths knowledge network. The width of the ties in each of the pairs indicates the number of times each found the other one satisfactorily helpful in knowledge sharing and collaborative experiential learning, hence stronger ties. Weaker ties show interactions/communications and stronger ties depict helpfulness and effectiveness.

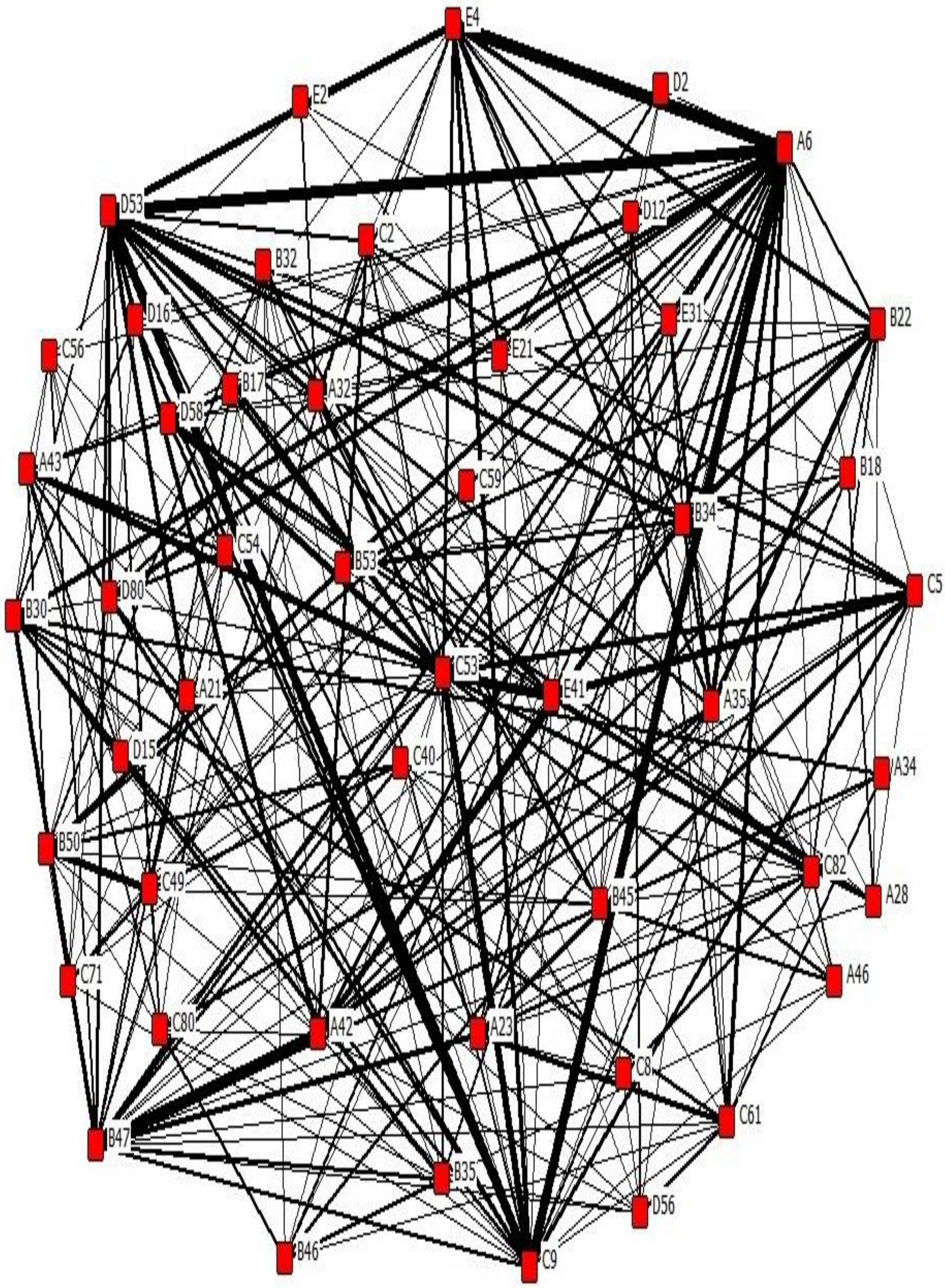


Figure 55: Strength and Viability of Student Ties in the OP3 (Maths Knowledge Network) – 2nd cycle

Table 59 offers the features of the maths knowledge network.

Density	39%
Distance-based Cohesion	0.60
Average Distance	1.866

Table 59: Connection Measures, Knowledge Network – 2nd cycle

It appears that density of the knowledge network was at a healthy level of 39% and it promoted knowledge sharing among the learners. In addition, it can be specified that the knowledge network had a considerably high cohesion level (60%). In qualitative terms, this figure means that agents of the networks were quite well-connected and engaged/interacted together well. The average distance of 1.866 in the network reveals that, on average, in less than two steps everyone can be accessed. Hence, collaborative experiential learning/practice between highly-skilled and low-skilled students is highly likely.

In addition, the researcher used three main centrality measures of degree, Eigenvector closeness and flow betweenness (see Table 60, Table 61 and Table 62). Table 60 refers to the degree centrality measure.

	1st Actor	2nd Actor	3rd Actor
In-Degree	A6 = 76	C53 = 57	D53 = 56
Out-Degree	D53 = 61	A6 = 58	C9 = 55
NrmInDegree	A6 = 17.59	C53 = 13.19	D53 = 12.96
NrmOutDegree	A6 = 14.12	A6 = 13.43	D53 = 12.73
Network Centralisation (Indegree) = 13.537%		Network Centralisation (Outdegree) = 9.992%	

DESCRIPTIVE STATISTICS

		1 OutDegree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
1	Mean	18.71	18.71	4.33	4.33
2	Std Dev	13.62	14.80	3.15	3.43
3	Sum	917.00	917.00	212.27	212.27
4	Variance	185.43	219.18	9.94	11.74
5	SSQ	26247.00	27901.00	1406.41	1495.04
6	MCSSQ	9086.00	10740.00	486.86	575.49
7	Euc Norm	162.01	167.04	37.50	38.67
8	Minimum	5.00	4.00	1.16	0.93
9	Maximum	61.00	76.00	14.12	17.59
10	N of Obs	49.00	49.00	49.00	49.00

Table 60: Degree Measure, Knowledge Network – 2nd cycle

Micro level of analysis: According to Table 60, agents A6, C53 and D53 had the greatest in-degrees. They were therefore in the position where most of the other agents were often asking them for help in the discussions around maths problem solving and experiential learning/practising. The highest out-degrees were for agents D53, A6 and C9. These agents are referred to as the most influential ones.

Meso level of analysis: From the perspective of distribution of degree centrality among agents, it is evident that the mean of 18.71 is very moderate for the 49 agents. In addition, there was a little more variability across agents in terms of in-degree when compared to out-degree. However, the in-degree range was also a little more than the out-degree range. The coefficient of variation for in-degree was 79% and for out-degree was 73%. Overall, it can be concluded that the knowledge network structure appears to be heterogeneous (slightly more heterogeneous in prominence (in-degree) than influence (out-degree)).

Macro level of analysis: Based on the network degree centralisation of 13.537% for in-degree (prominence) and 9.992% for out-degree (influence), it is justifiable to assert that there is not much degree centralisation or concentration in the knowledge network and that, in general, the advantages of knowledge level positions and power are equally distributed in the network.

Therefore, the enhancement in the knowledge network structure is another impact. Here there was a decentralised network structure where students with diversified levels of maths knowledge were connected together. In this scenario, skills development and performance improvement accelerated locally using learning/practice accomplishments in self-organised teams.

Table 61 shows the Eigenvector geodesic closeness analysis of the network.

	1st Actor	2nd Actor	3rd Actor
Eigenvector closeness	A6 = 0.404	C9& D53 = 0.370	C53 = 0.279
Network Centralisation Index = 49.76 %			

	1 Eigen Value	2 % of Variance	3 Cum %	4 Ratio
	-----	-----	-----	-----
1	35.44	29.1	29.1	2.75
2	12.88	10.6	39.7	1.16
3	11.08	9.1	48.7	1.11

Descriptive Statistics

		1 Eigenvec	2 nEigenve
		--------	--------
1	Mean	0.11	15.37
2	Std Dev	0.09	13.11
3	Sum	5.33	753.35
4	Variance	0.01	171.79
5	SSQ	1.00	20000.00
6	MCSSQ	0.42	8417.51
7	Euc Norm	1.00	141.42
8	Minimum	0.01	1.45
9	Maximum	0.40	57.08
10	N of Obs	49.00	49.00
11	N Missing	0.00	0.00

Table 61: Eigenvector Closeness, Knowledge Network – 2nd cycle

Micro level analysis: Using the scores of the Eigenvectors, the most central students who are globally influential in the leading pattern of the overall structure of the knowledge network can be identified. Evidently, A6, C9, D53 and C53 were the most central agents in the leading pattern of the network.

Meso level analysis: Table 61 provides the first three Eigenvalues for the knowledge network and assists with understanding the extent of the global, local and other pattern/trend of distances among students. The first Eigenvalue had 29.1% overall variance. This means that the main pattern in the knowledge network emerged from nearly one third of all distances among students. This is not a high percentage in the whole network and reveals that the leading pattern was not extensive. In addition, the ratio of the first Eigenvalue to the second was 2.75:1. This specifies that the leading pattern was 2.75 times more significant than the secondary pattern. Since the leading patterns was at least 1.5 times larger than the second pattern, the centrality measure is considered robust.

Macro level analysis: The Eigenvector centralisation index for the knowledge network was very moderate (49.76 %), thus implying a moderate level of concentration in the distribution of the actor's power for these three. However, the key actors in the knowledge network have been in various teams throughout the course of the extra maths sessions. In addition, low-skilled students referred to and asked for help from highly-skilled students. The 49.76% network centralisation was very moderate. Hence, there is no problematic inequality for the defined purpose of the network in developing maths skills and improving performance.

Table 62 shows the flow betweenness analysis.

	1st Actor	2nd Actor	3rd Actor
Flow Betweenness	A6 = 151.26	C53 = 132.13	B47 = 112.50
Flow nBetweenness	A6= 6.7	C53 = 5.86	B47 = 4.99
Network Centralization Index = 4.632%			

DESCRIPTIVE STATISTICS FOR EACH MEASURE

		1 FlowBet	2 nFlowBet
1	Mean	48.90	2.17
2	Std Dev	32.41	1.44
3	Sum	2396.14	106.21
4	Variance	1050.43	2.06
5	SSQ	168644.41	331.36
6	MCSSQ	51471.20	101.13
7	Euc Norm	410.66	18.20
8	Minimum	2.10	0.09
9	Maximum	151.26	6.70
10	N of Obs	49.00	49.00

Table 62: Flow Betweenness Measure, Knowledge Network – 2nd cycle

Based on Table 62, it is uncovered that A6, C53 and B47 were the most key mediators and brokers for knowledge sharing. In addition, the coefficient of variation for flow betweenness of students was moderate (0.66). The degree of concentration/inequality in the spreading of flow betweenness within the knowledge network was also as low as 4.632%. Hence, knowledge flows in the network very smoothly.

4.3.4.4. Results of Assessing Developments in Strategies

Implementing collaborative knowledge sharing and experiential learning in the students' knowledge network, there emerged feedback loops along the journey of the systemic solution. These feedback loops manifested the strategies developed for the teams and for the class, aiming at maths skills development and performance improvement (see Figure 56).

Figure 56: Gradual Developments in Strategies, Knowledge Network – 2nd cycle

Reflecting on the development of the strategies in the two cycles of the systemic solution in the extra maths sessions, Table 63 provides the analysis of each strategy (the letters beside the numbers in the first column show the strategy level. T refers to Team level and N refers to Network level).

	Evolving Strategies in the Knowledge Network	Analysis
1T	Creating the Friendly Teams: Team composition/assembly, clarifying teamwork and collaboration	Creating the enabling structures for the primary activities, through amplifying skills-mix in teams in order to manage the complexities of the required performance.
2N	Defining the governing rules	Agreeing on the identity and governing rules.
3T	Get to know the Tasks and roles	Focus on the primary activity specifications and clarification on knowledge sharing processes
4T	Communication, Team talk	Communication acts as an interaction mechanism to activate the knowledge varieties to be of use in the team.
5N	Attendance matters	Importance of self-organisation in personal life in order to be present in the sessions and to increase one's access to developmental tasks and knowledge varieties
6T	Time Management in the session: by preparing before the session	Importance of individuals' self-organisation in personal life to make time to engage more with learning contents beforehand by mechanism of amplification of their knowledge varieties at individual level prior to attending to the sessions. Hence the time saved can be used when applying the concepts (that are learned personally beforehand) in the teams' collaborative knowledge sharing and experiential learning.
7T	Size of the team matters	When team size was 8: Team's variety attenuation to make a balance between team's coordination tasks and the process of experiential learning for highly skilled students in the team. When team size was 3: Team's variety amplification by managing/increasing the number of team members to diversify knowledge/skills varieties and balance against challenges in collaborative maths' problem solving and experiential learning.
8N	Inviting/adding more highly skilled students to the extra maths sessions	Network's system four strategy: Innovative mechanism to help system three in regulating/managing the activities in system ones in each team.
9T	Importance of Quality of the answers vs. quantity of the questions solved.	Team goal re/alignment by judging/critiquing the goals, rules, norms and boundaries against team's performance (i.e. second-order learning in team).

	Evolving Strategies in the Knowledge Network	Analysis
10T	More questions and more practice in teams	Maths questions are vehicles for the collaborative experiential learning/practicing. An increase in the number of questions means variety amplifications and intensifications in system one's tasks in order to reach the required performance (i.e. skill development in answering the maths questions correctly) expected by system three (highly skilled students' approval).
11N	Creating an online Facebook group for informing/alerting students about the schedule of the sessions	Creating an online channel for system two: a channel for coordinating management tasks for the knowledge network
12N	More practice sessions	Linked with 6N and 9T, this strategy is about network's variety amplification in terms of increasing number of practice sessions for collaborative experiential learning on more questions in order to reach to the required skills quality and performance among all teams in the network compensating the time limit of final performance.
13N	Decision on online Collaborative learning/practice on Facebook	System four's innovative settlement on using the Facebook page as an extra (online) system one, for primary activities, in addition to face-to-face sessions (hence increasing the variety) as well as for when it is not possible to arrange face-to-face sessions (maintaining variety)
14T	More challenging questions for further skills development	System three observes the current performance and the readiness of system one for higher performance goals and acts upon by increasing the questions' level of challenge to further advance the skills thorough collaborative experiential learning/practicing on such harder question.
15T	More teamwork: More checks on the answers, discussions in team	System three star notifies system three to focus more on regulatory mechanisms of system one's primary tasks in teams, since system one is asking for more checks on the tasks.
16N	Decision for more Communication By whole class discussions	Variety amplification through knowledge brokering among teams.
17N	Decision for leading/organising two sessions by a highly skilled student	Emergence of a leader: Leadership development
18N	Decision for using the methods/structure and processes of this session for another module too.	Innovation: Ability of the system in reproducing itself. Autopoiesis.

Table 63: Analysis of Evolving Strategies in the Teams and in the Network

4.3.5. Stage 5: Reflection and Learning

At this stage, the researcher reflected on the process and impacts of the four stages performed earlier in the second cycle case study of the SCOR methodology. An interpretive approach was used to understand the impacts and to connect them together in a pragmatic fashion. The results are new insights, which are discussed in this section. Table 64 shows the main sources of the reflection.

Second Cycle: Reflection and Learning Stage	
Reflection and Learning from Stage One	Learning from Systemic Diagnosis
Reflection and Learning from Stage Two	Learning from Operation/Action Planning and Design
Reflection and Learning from Stage Three	Learning from Implementing the Operations/actions
Reflection and Learning from Stage Four	Learning from Evaluation and Assessment

Table 64: Reflection and Learning – 2nd cycle

In performing stage 1, i.e. diagnosis, while the management processes and structure of APS-Maths at BSUKU did not change in the second cycle, the researcher ensured to have reached a comprehensive view of the new cohort of students and their leaning processes. This was through ethnographic observation of the learning processes of new students and analysis of their social network. The insights and understanding gained at this stage were rich and deep in terms of varied governing rules of learning in different streams of students, as well as type of streaming strategy, which created structural separation in the learning network of students. Hence, managing students' cognitive capital and their learning processes was undermined. The results of the diagnosis in the learning situation and processes were similar to the first cycle and this paved the way for the researcher to conclude that the use of diagnosis in cycle 1 (Table 30) is highly relevant for the second cycle.

With due attention paid to the learning which emerged from the first cycle and the systemic diagnosis, the researcher revised the design of the systemic solution plan for better performance. This was achieved through using the last four years of APS performance, in order to relate to Beer's (1972) actuality, capability and potentiality measures of the performance success in the system. In addition, managing students' social capital was similar to the first cycle, through recognising the ratio of highly-skilled to low-skilled students. Referring to the reflection stage in the first cycle, the focus for the second cycle was on operational plan 3. Similar to the first cycle, the design therefore included facilitating a session for familiarising students with the basics of the viable system model, reaching agreements on the purpose and identity and creating goals for skills development and performance improvement. The researcher used the interpretation of domains of viable knowledge for designing/structuring functionalities of the solution. This was a method of collaborative knowledge sharing and experiential learning/practising in guided self-organised teams within the extra maths sessions (which turned into a maths knowledge network).

The implementation stage in the second cycle was based on activities of the first week as well as second week and onwards. Operationalising the activities proved quite non-problematic. Students were informed of these sessions during their induction day. Word of mouth from the previous year's students also had an effect on their willingness to participate. In fact, second-cycle students were more proactive in asking when and where the extra maths sessions (systemic solution) would take place.

The suggestion for leading a maths session as well as the initiative for adopting the same method of collaborative experiential for another module emerged earlier in the second cycle. This reveals more self-organisation and more learning goal orientation among the second-cycle students. Further, the presence of the researcher as a tutor/facilitator in the maths workshops/tutorials (formal lecture sessions) was an advantage because students could share their willingness to attend the extra maths session or ask questions about the systemic solution (extra maths sessions) straight away within the workshops/tutorials. This suggests that becoming an internal member of a system can largely facilitate the coordination and dynamic of the developmental change programmes.

The researcher then evaluated the impacts of implementing operational plan 3. The results showed that the systemic solution through operational plan 3 had further success in developing students' maths skills and in improving the performance, in the second cycle. Table 65 shows the rate of fail and the change which occurred in the years 2012-13 to 2016-17.

Admission	Teaching/Learning Structure	Rate of Fail
2012-2013	Maths Workshops	16.25%
2013-2014	Maths Workshops	20%
2014-2015	Maths Workshops	26.15%
2015-2016	Maths Workshops + Tutorials sessions	22%
	Maths workshops + Tutorial sessions + systemic solution	13%
2016-2017	Maths Workshops + Tutorials sessions	20%
	Maths workshops + Tutorial sessions + systemic solution	10%

Table 65: Change in Rate of Fail – 2nd cycle

With reference to performance measurement (see Section 4.3.2.1.1), Table 65 reveals the underperformance in the APS-Math as the evolving system. While it was expected that students' performance would reach 86%, the result shows 80% success in students' maths performance. The situation for those who attended the systemic solution (extra maths sessions) was different. The rate of success was 90% and is above the performance expectation of 86%. Since this performance appeared to happen in both cycles, it can be concluded that performance improvement in APS-Maths needed something more than merely adding tutorials to its structure. The method used in the systemic solution proved to provide beyond the performance expectations.

One might argue that receiving an additional 25-30 hours for extra support/practice normally helps in achieving better results. However, this was not the case in the present research. Attendance at these sessions was not compulsory. Students involved in the maths knowledge network attended the sessions very organically and mainly as a replacement for attending their timetabled tutorials. Reflecting on their attendance at the maths knowledge network (six sessions on average per person), it is evident that they did not get such a huge number of hours for extra support. Those who were not involved in the maths knowledge network had, on average, five sessions of tutorials attendance. It was in fact the self-organised method of collaborative learning and knowledge sharing that made those involved in the maths knowledge network perform better.

In comparing the results of 2012-13 with those of 2015-16, it is important to keep in mind that the rate of fail was reduced despite admission of more low-skilled students (see Section 4.1.2.1). Hence, though the result of 2015-16 with the systemic solution does not seem like an impressive change, based on the contextual information about the two cohorts and students' prior maths qualifications, it is safe to argue that this was a good change.

The researcher also learned that the combination of the viable system model and the social network analysis used in the systemic solution led to recognition of heterogeneity in the maths knowledge network as well as cohesion and density of 60% and 39% respectively.

In addition, when agent A6 offered to facilitate and run two sessions using a method similar to that employed by the researcher, the emergence of a 'knowledge leader' became evident. This person was one of the highly-skilled students form stream A (see Section 4.3.3.1.1.3.1). The social network analysis of the knowledge network also revealed that he was one of the most influential (measure of degree centrality), most central/powerful in the leading pattern (Eigenvector degree closeness measure) and a key knowledge mediator/broker (flow betweenness measure). Feedback given by knowledge brokers revealed that they were involved in different key activities. For instance, one reported "too many questions to answer. Quadratic equations are hard. We need to do more on that". This knowledge broker was involved in early and continuous needs evaluation for his/her team. Moreover, another broker mentioned "lets create a Facebook group to have an online platform" and "we have to practise more questions and share things on the Facebook page". This illustrates that said broker scanned the environment and looked for ways to resolve his/her team's maths' problem-solving issues. Additionally, by mentioning "do the work with those who know how to answer the questions" as well as "meeting new people" and/or "we would ask for help when stuck", they intended to and actively sought to develop their network. In effect, according to Contractor et al. (2000), they are positioned to share knowledge with others including those who do not share knowledge. Further, another knowledge broker stated that "we have good team collaborations and a friendly environment", which indicated the facilitation of learners' skills development through knowledge sharing. Moreover, the above-mentioned examples suggest brokers' own capacity development based on evidence to inform their decisions whether and when to broker for the knowledge from outside their team. Evidently, these key activities are in line with Dobbins et al.'s (2009) characteristics of knowledge brokers. Overall, knowledge brokering among teams of learners in this case study coincides with Hartwich and von Oppen (2000) and Loew et al. (2004) to confirm that knowledge brokers are facilitative to the processes of learning in the knowledge network.

Further, an innovative example of system self-reproduction was evident when agent C53 suggested using the same method of extra maths sessions for their learning in the accounting and financing module. He/she coordinated/managed/led a few sessions for this purpose (see Section 4.3.3.1.1.3.2). Social network analysis showed that C53 was an influential as well as a central /powerful agent in the leading pattern and a key knowledge mediator/broker in the knowledge network.

Moreover, this research showed the capacity of the maths knowledge network to empower students to take charge of their own as well as their collective learning. They recognised the importance of meta-systemic roles for their knowledge network in order to organise/regulate the progress in maths skills development. Students also recognised the superiority of the methods used. This became evident when they nominated the researcher as the best tutor at the student-led teaching awards. The researcher was selected as best tutor at BSUKU.

Finally, the researcher learned that the two cycles of the SCOR methodology had similar quantitative and qualitative/emerging results and that with the learning and experience gained from the first cycle, the results of the second cycle operation were enhanced further. The researcher and the module leader discussed the results of the systemic solution. There was agreement in terms of maths skills development and performance improvement beyond the expected results.

4.3.6. Chapter Conclusion

This chapter provided the process of action research based on the SCOR multi-methodology. The purpose was to investigate the reasons for re-occurring failure in learning performance and to develop and implement solutions for students' skills development and performance improvement. It started with examination of the area of application/concern. Two cycles of action research were then performed. Each cycle comprised five stages, namely diagnosis, action planning, implementation, assessment, and reflection/learning. The research was performed in an academic module at a UK-based business school. This chapter revealed the level of success as well as lessons to be learned for management of learning and skills development.

Chapter 5: Thesis Discussions

5.0. Introduction

In this chapter the researcher provides the discussions on 1) assessing the design of soft-OR multi-methodology; 2) on using a soft-OR Multi-Methodological approach; 3) on VSM+SNA as a combinative tool for learning about complexity; 4) on VSM+SNA for leadership development and autopoiesis; and 5) on evaluating the multi-methodological action/operational research.

5.1. On Assessing the Design of Soft-OR Multi-Methodology

There exists a growing amount of research using soft-OR multi-methodologies (Espinosa and Walker, 2013; Paucar-Caceres and Espinosa, 2011; White, 2009). However, the initial thought on using a multi-methodology in this research, by combining a soft systems account of OR with Canonical Action Research methodology, as well as using a variety of methods and tools, emerged based on a literature review of knowledge sharing (discussed in Section 2.4.1 and Section 3.2.5). Neither the role of OR in knowledge management (KM) nor the role of OR in KM within social networks are clear (Edwards et al., 2009). According to the literature review of this thesis, there is a scarcity of studies on knowledge sharing that use OR, soft-OR or action research with social networks. Flood and Jackson (1991), Mingers and Brocklesby (1997), Zhu (1998) and Ormerod (2001) are the first to advocate for designing research multi-methodologies using soft-OR. The researcher used Mingers and Brocklesby's (1997) framework for mixing methodologies and evaluated the design of the soft-OR multi-methodology of this research.

As discussed in Section 3.2.1 and Section 3.2.5, the combination of CAR and F-M-A represents a multi-methodology combining hard and soft systems methodologies, respectively. The researcher acknowledges that the paradigmatic epistemological and ontological assumptions of the two are different. Yet, the pragmatist philosophy of this research made it possible to capitalise on the advantages of both and to rectify the pitfalls of each. Although the SCOR multi-methodology is a result of combining two research methodologies, namely F-M-A and CAR, it is important to note that each of the stages (diagnosis, action planning, implementation, evaluation and reflection) has also been designed based on a combination of various methods and tools. The green areas in Table 66 and Table 67 relate to dimensions and characteristics of the SCOR multi-methodology based on Mingers and Brocklesby's (1997) framework. In effect, the strengths of CAR are in covering the material/objective aspects in all four stages of the framework. The SCOR multi-methodology also comprises two more stages for evaluation and reflection. According to Mingers and Brocklesby (1997), the soft system methodology attends to the personal/subjective level at all four stages of the framework. In addition, it covers social, personal and material aspects in the appreciation stage. VSM supports three stages of analysis, assessment and action at social and material levels (see Table 66).

SCOR Multi-Methodology Stages	Mingers and Brocklesby's Framework	Social World	Personal World	Material World	
Area of Application	**Appreciation of**	**External Environment:** Competitive Relations, Patterns/trends of current situation	**External Environment:** Individual positions, circumestances and situations	**External Environment:** Resources, Processes, and Infrastructure	**Framework of Ideas: Focal Theories and Instrumental Theories**
Diagnosis		**Internal Context:** Norms/ codes of Practices, Governing rules, Power relations	**Internal Context:** Varied perceptions on interactions and relations; Different ideas on identity	**Internal Context:** Resources, Processes, Circumestances	
	Analysis of	Social interaction problems, learning issues, Power balance, Performance issues; Structural issues, Communication	Varied knowledge type; different skills level; differing performance levels	Underlying causal mechanisms; Misalignment of issues and solutions	
Action Design	**Assessment of**	Realistic ways to change the power and structural distances; Viable methods that enable communication and collaboration; Feasible approaches to collective knowledge sharing, experiential learning, skill development and performance improvement	Alternative concepts and constructs	Alternative ways of organisation; Alternative ways of arranging the structure	
Operations/ Action	**Action to**	Orient/empower learners towards goals/identity; Facilitate collaborative knowledge sharing and learning/practicing among learners; Develop learners' skills; Improve their performance	Create consensus; Generate personal determination and motivational resources in developmental experiences	Choose and apply best alternative	
Evaluation	**N/A**	Change in collective skills level; Change in collective performance; Change in motivation level; Change in collective developmental strategies; Change in knowledge network; Emergent and unplanned outcomes	Change in personal understanding and insights; Change in individual skills level; Change in personal performance	Denser, more interconnected network; Improved performance	
Reflection	**N/A**	Organisational understanding and reflective practice	Personal insights and reflective practice	Reflective practice	

Table 66: Dimensions of SCOR multi-methodology on Mingers and Brocklesby's (1997) framework

This research agrees with Espinosa and Walker's (2013) contention that F-M-A and VSM fit well and complement each other. For example, in order to agree on identity at the beginning of the present project, soft-OR tools such as TASCOI were used to generate understanding, insights and consensus. SNA was also useful to highlight structural issues, disconnections, fragmentations and missed opportunities. The main theories involved in this research were VSM and SNA (VSD and domains of viable knowledge are methods which stemmed and were developed from VSM). Table 67 reveals the mapping of SCOR multi-methodology in Mingers and Brocklesby's (1997) framework. The combination of methodologies and methods in the SCOR multi-methodology covers all stages and levels in this framework.

SCOR Multi-Methodology Stages	Mingers and Brocklesby's Framework	Social World	Personal World	Material World	
Area of Application	Appreciation	Attride-Stirling's (2001) Thematic analysis; Espejo's (1999) TASCOI; Rogers's (1969) facilitation theory	Attride-Stirling's (2001) Thematic analysis; Espejo's (1999) TASCOI; Rogers's (1969) facilitation theory	Attride-Stirling's (2001) thematic analysis of external Context	Framework of Ideas: Focal Theories and Instrumental Theories
Diagnosis	Analysis	Beer's (1985) viable system diagnosis method; SNA (qual and quant); Nahapiet and Ghoshal's (1998) three dimensions of social capital Theory; Beer's (1972) viable system theory for Performance measurement; Achterbergh and Vriens's (2002) domains of viable knowledge Dragoni et al.'s (2009) leadership development	Beer's (1985) viable system diagnosis method; SNA (qual and quant); Nahapiet and Ghoshal's (1998) three dimensions of social capital Theory; Beer's (1972) viable system theory for Performance measurement; Achterbergh and Vriens's (2002) domains of viable knowledge Dragoni et al.'s (2009) leadership development	Beer's (1985) viable system diagnosis method; SNA (qual and quant) for analysis of internal Context	
Action Design	Assessment	Feasibility discussion	Feasibility discussion	Feasibility discussion	
Operation/ Action	Action	Implementation	Implementation	Implementation	
Evaluation	N/A	VSM Performance assessment, Statistical Analysis; Evaluation of gradual change in Skills Development; SNA; Developments in network strategies	Change in personal understanding; Change in individual skills level; Change in personal performance	Improved performance	
Reflection	N/A	Reflective practice and learning on diagnosis, action planning, implementation and evaluation	Reflective practice	Reflective practice	

Table 67: Mapping SCOR multi-methodology on to Mingers and Brocklesby's (1997) Framework

5.2. On Using a Soft-OR Multi-Methodological Approach

This research started with exploring the area of application/concerns and the background analysis of the problematic situation in the environment that surrounded the case study business school. This ensured an in-depth understanding of the root causes of the inherited problem. The next stage was to diagnose the internal organisational situations relevant to the issues and concerns. As Espinosa and Walker (2013) suggest, a good starting point for resolving the issues in a project is to agree on identity and to find the core issues. Combining soft-OR tools/methods drawn from VSM and SSM was useful in the diagnosis stage and ensured a shared understanding, thus allowing possible appreciation of multiple views. Therefore, the issues diagnosed in this approach were not built upon the researcher's perspective, but rather on the internal people at the management level as well as at the learners level in the business school. In this sense, the use of soft-OR methods and tools was found particularly relevant at the beginning of managing this complex project, thus reconfirming Winter (2006). Notably, the soft-OR tools used in this research were drawn from theories referred to as instrumental and focal theories in the canonical action research methodology. The instrumental theories helped the researcher in explaining, diagnosing, planning and evaluating the events and processes. Examples of instrumental theories are Beer's (1972) viable system theory, Beer's (1985) viable system diagnosis method, Freeman's (2000) social network theory, and Nahapiet and Ghoshal's (1998) dimensions social capital theory. Focal theories intellectually guided the researcher in leading the action-orientated solution. Rogers' (1969) facilitation theory, Achterbergh and Vriens' (2002) domains of viable knowledge, and Nahapiet and Ghoshal's (1998) dimensions of social capital theory are examples of focal theories in the cases of this research.

The multi-methodology of this research promoted Davison et al.'s (2012) CAR methodology by introducing area of application (A) from Checkland's (1985) F-M-A Soft systems account of AR, in order to create an in-depth contextual understanding of the interlinked problematic issues between the business school and the environment within which it operates. This ensured that that diagnosis stage in the CAR methodology was focused on discovering the internal organisational problems, reaching a clearer understanding of the issues. Therefore, better insight from both internal and external situations provided opportunities for innovative solutions in the business school to handle the environmental complexities more effectively, as discussed in Section 4.1.3.

The multi-methodology also promoted Checkland's (1985) F-M-A Soft systems account of AR by specifying its framework of ideas to be drawn from relevant theories, and by classifying said ideas into two categories, namely instrumental and focal theories – an idea from the role of theories in CAR. Moreover, since instrumental theories have a projecting role in the selection and assessment of focal theories, the interdependencies among F, M, and A were more relevant. Similarly, CAR's cyclical process model being enriched/supported by focal and instrumental theories contributed to additional clarification of M (methodology) in F-M-A in a more structured way (see how Figure 57 and Figure 58 formed Figure 59). The learning in and about methodology then derived/emerged throughout each of the stages in research.

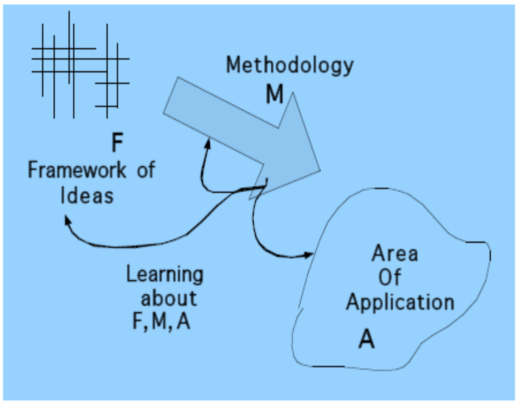


Figure 57: Checkland's (1985) F-M-A

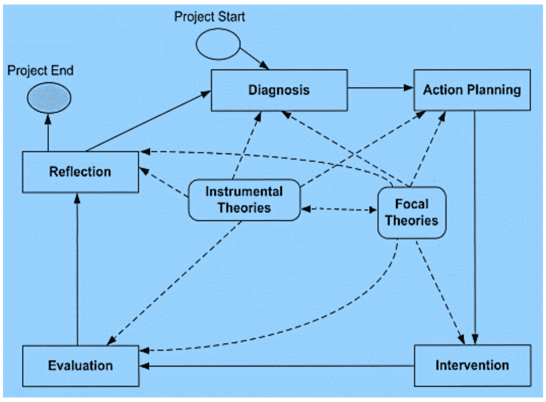


Figure 58: Davison et al.'s (2012) CAR

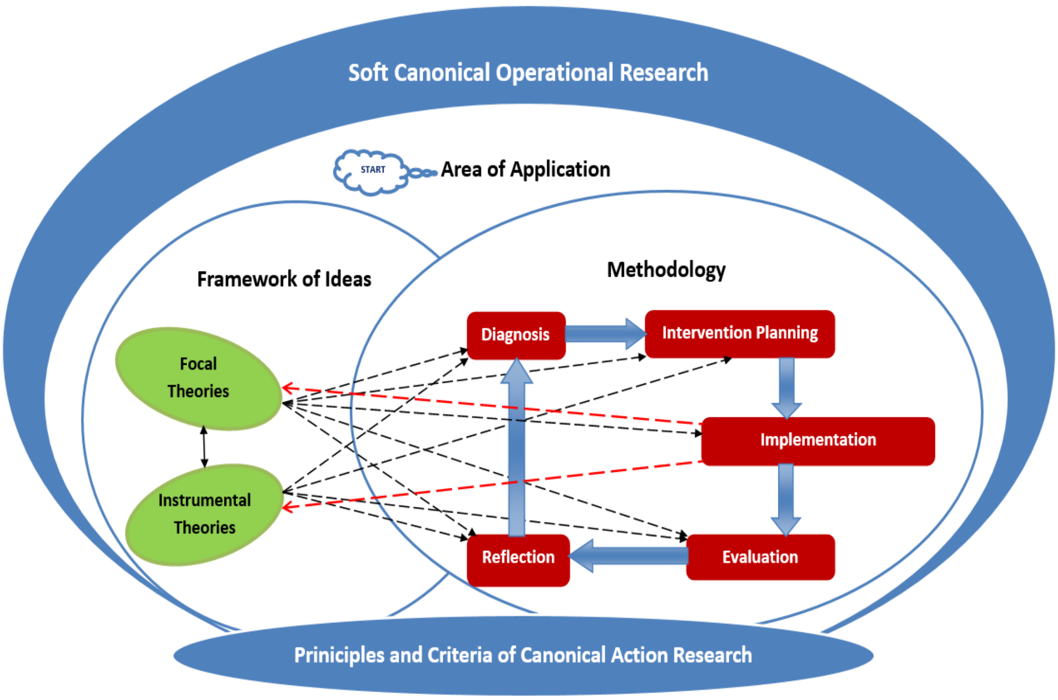


Figure 59: SCOR Multi-Methodology – Combining Checkland's (1985) F-M-A and Davison et al.'s (2012) CAR

Further, the SCOR multi-methodology of this research became even more rigorous after adopting Davison et al.'s (2012) CAR principles and criteria.

5.3. On VSM + SNA as a Combinative Tool for Learning about Complexity

The soft-OR study in this research was very beneficial in learning about the practical use of VSM and SNA. VSM and SNA were used as a combinative interpretive tool (through the method note (see Appendix 2) and team composition) in supporting learners' understanding of/learning about the organisation/reorganisation of their collective learning within the evolving maths knowledge network.

Referring to cybernetics of the observer (Von Foester, 1981) and deeper perceptions of cognition (Maturana and Varela, 1980), this research shifts from the classical functionalistic perspective of VSM, offering a theoretical and practical example.

The diagnosis of systemic issues was based on Espinosa and Walker's (2011) VSM meta-questions, as well as qualitative social network analysis (i.e. ethnographic observation). This created a learning context in which to understand the issues and concerning circumstances. Subsequently, the plans of action were supported by the predictive information/knowledge (Ay et al., 2012) of such learning. Hence, the action plans were considered as guided self-organisation mechanisms for the BSUKU to tackle the concerning issues at the meta-systemic level of the APS-Maths project.

The design and implementation of the maths knowledge network (extra maths sessions) at the learner's level were underpinned by the VSM theory of organisational viability and built on Achterbergh and Vriens' (2002) domains of viable knowledge. These two stages also provided a learning arena in which a shared understanding among learners was developed (see Section 4.2.3.1.3.1). Learners could also make decisions/strategise individually and in teams in line with organisational viability criteria for their maths knowledge network (see Section 4.2.3.1.3.2).

During the first week's activities (Section 4.2.3.1.3.1), which included a brief introduction to VSM, the leaners gained an understanding of operational and meta-systemic tasks. This gave them the powerful vehicle to regularly think and re-think about the organisation of their maths knowledge network. They became familiar with a viable method of collective knowledge sharing and collaborative experiential learning/practising, which assisted them in effectively dealing with complex maths activities and tasks. During the second week's activities, and those which followed (Section 4.2.3.1.3.2), they found the extra maths sessions in their maths knowledge network very useful, and they could use these to manage to overcome their initial fear and anxiety, and brainstorm and narrate the strategies that they wanted to peruse for the betterment of their own learning transformation/performance. Examples of these strategies are more communications, more experiential learning sessions, using online platform for announcements, searching for/inviting more highly-skilled peers to the sessions, and restricting team size.

In addition, the distinction of the facilitative methods used in the knowledge network provoked innovative thoughts among learners in both cycles. First, one of the learners asked to facilitate/lead a maths session (knowledge leadership, proven by SNA) and said learner did just that. Second, in another instance the learners decided to implement the same processes/methods of collaborative learning/practising for another module in the first year of their undergraduate course. This showed their understanding of the viability and identity, as well as their ability to use such understanding in another module.

Further, the researcher was acting as the facilitator for students in their process of learning in both first-order learning and second-order learning, as well as in their experience throughout the continuous transition from one to another (i.e. skills development).

One constraint of this research was that students' VSM learning was limited to basic concepts and a discussion on the method of VSM application in the maths knowledge network. At this level, the learning was to the point and successful. However, from one side, there was a fear that if the researcher provided expert VSM information, then students may experience difficulty in understanding the terms and concepts, since they were first-year students at undergraduate level and mainly without work experience. From the other side, the maths was, by itself, a difficult subject to learn. Hence, the researcher consciously decided to introduce the basic VSM ideas only. Future research may seek to provide more insights into whether VSM being taught by an expert has a more positive/negative effect on the maths learning of first-year undergraduate students. There is also the question of what would be the effects of expert VSM teaching on teams' knowledge brokering and on the leading patterns of their maths knowledge network? Better insights and understanding are sought in this regard.

5.4. On VSM + SNA for Leadership Development and Autopoiesis

Another key benefit of this research was learning about how VSM and SNA are facilitative in developing knowledge leaders as well as in discovering the ability of the system to reproduce itself.

In this soft-OR study, the researcher implemented Achterbergh and Vriens' (2002) domains of viable knowledge, in which the first two domains are about setting strong learning goals and about defining the identity of the maths knowledge network. In accordance with Day and Sin (2011), goal setting/alignment was a process of self-organisation that guided the primary tasks and contributed to perseverance/determination and motivational resources in developmental experiences.

Another process of guided self-organisation was facilitated through team composition with the ratio of 1:4, which created a supportive sphere for low-skilled learners with strategic access to a highly-skilled peer. In keeping with Seibert et al. (2017), Eisenberger et al. (2014) and McCauley et al. (2006), such access proved to provide low-skilled learners with an immediate key resource available within their teams to assist them in experiencing the maths skills development in the knowledge network.

In addition, the application of domains of viable knowledge in this research established the conditions and structures for learners' collaborative experiential learning/practising in solving maths questions, i.e. '*primary operational tasks'*. The maths questions to be solved were also provided. This gave the learners access to highly developmental tasks and provided them with the opportunities to gain *continuous experience* in solving the challenging maths questions individually, as well as within and between the teams in the knowledge network. VSM also set the foundations for the highly-skilled learners and those who had recently become skilled, to gain access to the developmental tasks that were pertinent to management of experiential learning/practising activities, *i.e. 'meta-systemic tasks'* (a second-order learning by co-designing the tasks/methods to address them). This was achieved through responsibilities for checking/helping other low-skilled learners, brainstorming and approving plans for rectifying the problems, as well as modifying the goals/procedures that came up. Learners therefore also gained *continuous experience* on these developmental meta-systemic tasks.

Overall, based on the above, it was evident in this research that the VSM application in the context of learning management was characterised by (1) strong learning goal orientation,

(2) providing access to developmental tasks (both primary and meta-systemic) and (3) permitting the accumulation of experience on both primary tasks and on meta-systemic tasks. These features appear to coincide with Dragoni et al.'s (2009) criteria of leadership development (see Section 2.4.3). In this vein, SNA was useful to capture the power, dominance and centrality of the emergent knowledge leaders. This is in agreement with Deng and Chi (2015), Owen-Smith and Powell (2004), Hansen (1999), Wasserman and Faust (1994) and Brass (1984). The researcher therefore considers that the application of VSM+SNA for knowledge sharing and collaborative learning in an educational context is an effective approach for enhancing the process of leadership development. Through the combination of VSM+SNA, it was not only possible to answer the question of why knowledge leaders had chances to emerge, but also to spot who is a knowledge leader in the knowledge network. Given Day and Dragoni's (2015) call for holistic empirical studies on the developmental perspective regarding leadership through designing methodologies that generate understanding about its underlying mechanisms and processes, as a future area for research, it will be interesting to investigate whether the application of VSM+SNA in other contexts provides empirical evidence for leadership development.

Moreover, according to Malekovic and Schatten (2008), leadership is the key component for autopoiesis to emerge. The examples of autopoiesis (i.e. the ability of the system to re-produce itself) in this research refer to the occasions when a student creatively suggested implementing the same structures/processes/methods of the knowledge network for another module. This was successfully carried out in both cycles by the students. In this arena, by accepting that the application of VSM+SNA is an effective leadership development approach, which helps to identify knowledge leaders in the network, it can therefore be suggested that, in this way, the emergence of autopoiesis is explained/accommodated by the original VSM theory.

5.5. On Evaluating the Multi-Methodological Action/Operational Research

What a specific multi-methodology action research proposes is a model of the real-world situation. Multi-methodological approaches to action/operational research are yet lacking a prescribed or systematic means for their impacts evaluation (Espinosa and Walker, 2013; Jackson, 2003). As Mingers and Rosenhead (2004) indicate, at times the outcomes of multi-methodological action/operational research are naturally intangible (e.g. reaching better insights or an enhanced understanding). Therefore, the assessment of these outcomes' contribution and effectiveness becomes challenging. However, the combination of qualitative and quantitative analyses of both VSM and SNA showed that some of the learning that naturally and intuitively occurs during VSM-orientated action processes can be measured and supplemented by analytical techniques. Following previous studies combining VSM and SNA (Al-Hinai, 2017; Espinosa and Walker, 2011; Cardoso, 2011; Knowles, 2011; Watts, 2009), this research also provides examples of how such combination can be achieved and the nature of measurements that can be implemented.

5.5.1. Effectiveness of Systemic Multi-Methodological Research

The utilisation of Mingers and Brocklesby's (1997) framework to mix the methodologies and methods was useful in confirming whether the subjective and objective matters in the appreciation, analysis, assessment and action stages in the three levels of social world, personal world and material world have been covered. As discussed in Section 5.1 (see Table 66 and Table 67), the SCOR multi-methodology of this research has striven to cover all stages and levels of the Mingers and Brocklesby (1997) framework.

After two cycles of action research, there remained no doubt that the solution offered and implemented in this research was beneficial, leading to a number of positive outcomes (briefly discussed below). The strengths of this research were its diagnosis and action design stages, in which issues in processes and structures were identified and possible solutions were designed. Carrying out the designed plans in the next stage then led to desirable outcomes as well as valuable learning and insights. From a project management level perspective, the core purpose of the solution in terms of performance improvement was achieved beyond the planned results, in both cycles (see Section 4.2.2.1.1, Section 4.2.5, Section 4.3.2.1.1.1 and Section 4.3.5). This improvement was due to continuous skills development at the student level. At this level, the skills-mix in teams led to better and more effective interactions, communication and tasks allocation among learners. In addition, as part of organisational cybernetics, this study presented a new approach to using VSM as a focal tool for developing the structures and processes of collaborative experiential learning. The researcher also used VSM as an interpretive instrument for understanding/learning about self-organisation, leadership development and autopoiesis in a maths knowledge network. In addition, Achterbergh and Vriens' (2002) domains of viable knowledge were used to support the learners in taking control of their own learning in a more informed way, through making decisions for improvements in their knowledge network. The learners also reached a clearer and a shared understanding of their learning tasks' complexities as well as the communication patterns within the processes of knowledge sharing and collaborative experiential learning.

The researcher felt that this could not be achieved through common sense or via generic conceptual models such as SSM as effectively as through VSM. While in SSM social agents structure their generic tasks in order to resolve the issues, SSM is silent in the provision of theory and instruments for diagnosing organisational problems or designing the remedial actions. The VSM clearly does this, as discussed in Section 4.2.1 and Section 4.2.2. The nature of SSM elucidations/solutions is also intuitive and based on participants' current insights, whereas the solutions which emerged from VSM, as the methodology of this research did, generated a deeper understanding which was related to self-origination mechanisms as well as issues of viability in the organisation (discussed in Section 5.3). Hence, the consistency in the viability theory of VSM permitted learning about complexity management in organisations in more innovative ways. In other soft-OR methodologies, the importance of social agents and their issues do not come first in the rank of priorities for achieving the results, since the researcher's aim is to support and fulfil certain organisational needs (e.g. strategic planning, managing projects, products development, etc.).

Instead, the VSM approach in this research focused on learners' enablement and empowerment through supporting them in recognising their learning difficulties and by encouraging communications/social interactions in the knowledge network. With their active engagement and participation in implementing the solutions/strategies (which they co-designed), the social agents became owners of the success. For instance, the method note (see Appendix 2) developed based on the domains of viable knowledge was used as an analytical tool to help learners focus on their areas of skills weaknesses (primary tasks) and to re-organise their team's goals/objectives and the network's knowledge-sharing strategies (meta-systemic tasks) around them, which showed transformation in learning as well as in management of learning. These transformations resulted in an increased success in performance (Section 4.2.5 and Section 4.3.5) and in a more cohesive network with a heterogeneous structure (Section 4.2.4.2.3 and Section 4.3.4.4), as well as the emergence of leaders and the system's ability to reproduce itself (Section 4.2.3.1.3.3 and Section 4.3.3.1.1.3) in both cycles.

Moreover, learners in the maths knowledge network felt that their learning was effectively guided and that they learned how to learn collectively through detecting and implementing more viable changes and better strategies for their learning performance improvement. They learned that self-organisation through knowledge sharing in a team enhanced their experiential learning and they felt more confident about the maths skills achieved in each session. Throughout the sessions designed to find a solution, the collaborations among teams also created a consensus for the knowledge network in order to evolve and move forward.

However, the researcher acknowledges the need for further research to confirm how effective the approach in this research will be in other knowledge networks e.g. in knowledge networks that deal with types of knowledge other than the tacit type. The key mechanisms for dealing with interplay between tacit knowledge and explicit knowledge are social interactions and experiential learning/practising. However, do these mechanisms work for areas/topics that handle implicit knowledge in education or in other contexts (e.g. political sciences, tourism, health sciences, etc.)? Equally, echoing Verburg and Andriessen (2011), it would be desirable to further investigate how this research approach will affect things in different basic types of networks (e.g. informal networks, Q&A networks, strategic networks and online strategic networks) in terms of the need for designing different operational and management/organisational supports?

This research highlighted some of the core issues at the student and management levels which hindered learners' knowledge sharing, learning, skills development and performance improvement (see Table 30), and illustrated an effective contribution from a soft-OR approach for managing the complexities involved. This was undertaken in order to advocate an innovative way of using soft-OR in the context of education for knowledge sharing and experiential learning as well as to epitomise how it has been applied in the two cycles of a case study. The researcher did not have the intention to present a fully established/tested soft-OR multi-methodology, but rather one 'with potentials to test'. The researcher acknowledges that there is a need for further testing of this multi-methodological action/operational research in other contexts so as to develop its scope of transferability.

5.5.2. Robustness of the Systemic Action/Operational Research

Mingers (2011) questions the robustness of the soft-OR case studies. Robustness becomes pivotal when the proposed systemic operation/action research is about setting out the scientific methods or those methods that pursue robustness of knowledge propositions (Midgley et al., 2013). Despite sharing this limitation, similar to other soft-OR approaches, this research was an inductive study and was exploratory in nature. The researcher gained insights through learning and reflections on how to better facilitate the process of self-organisation in teams. Hence, in the second case study cycle, the learners could more collaboratively share their knowledge and go through the team's cycles of experiential learning and practising. It is also important to report that the researcher became more open-minded and provided fewer ready-made directions, but asked the learners more about their own thoughts in their process of solving the questions in the team as well as facilitating further teamwork. This is where Rogers' (1969) facilitation theory became even handier in the researcher's own learning. In addition, with reference to the goal of the APS project in the BSUKU in terms of maths performance improvement, the use of Beer's (1972) viable system performance measurement proved that the multi-methodology action/operational research has been effective in students' skills development and performance improvement beyond expectation in both cycles (as discussed in Section 4.2.5 and Section 4.3.5). Further, in both cycles, the network of learners became denser, of higher cohesion, and with much lower power distances. SNA proved to be a powerful technique with which to identify and present these characteristics, as well as a vehicle for evaluating the power structure that emerged in the learner's knowledge network. The latter was useful in explaining the unforeseen events of knowledge leadership and the ability of the system for self-reproduction that emerged in both cycles through the leading patterns.

5.5.3. Legitimacy of the Systemic Action/Operational Research

The concerns over the legitimacy of the multi-methodological action/operational research pertain to whether the research approach is suitable. Based on Midgley et al. (1998), in order to create the foundation of legitimacy, an iterative process of thinking was needed throughout all of the actions and operations by reflecting on whether the suggested actions were aligned with the goals/aims/objectives of the learner participants and the case study business school, as well as whether the power balance was sufficiently addressed. With the pragmatist worldview in this research, which conveyed a goal-orientated approach, it was possible, at the diagnosis stage, to uncover the unaddressed knowledge power distance in maths teaching/learning between the learners and the teaching team as well as among learners of different groups (due to streaming strategy). In order to deal with this issue, the researcher considered management of social capital based on Nahapiet and Ghoshal's (1998) theory. The evaluation of social network analysis in both cycles showed that the two problems have been eliminated, to the scale that the cyclical systemic solution was implemented.

5.5.4. Rigour and Quality of the Systemic Action/Operational Research

In order to assess the rigour, relevance and quality of the systemic action/operational research, the researcher used Davison et al.'s (2012) principles and criteria of canonical action research. Table 69 shows how each criterion has been met in the two case studies, referring to the specific sections. Reflecting on Table 69, it is justifiable to claim that the rigour, relevance and quality of the systemic action/operational research was maintained, through meeting the principles and criteria of canonical action research.

P1. Principle of a researcher-client agreement	
C1a. Did both the researcher and the client agree that CAR was the appropriate approach for the organizational situation?	Yes, there was a meeting with the module leader and teaching/tutorial team. There was also discussion with students in the first week of the extra maths sessions. All discussed in section 4.1.1.
C1b. Was the focus of the research project specified clearly and explicitly?	Yes, the focus of the research was argued/discussed collaboratively with the module leader. This was discussed in details in section 4.1.1
C1c. Did the client make an explicit commitment to the project?	Yes, module leader did support the project. She explicitly showed commitment whenever support was needed. This is discussed in sections 4.1.1 and 4.2.1.1
C1d. Were the roles and responsibilities of the researcher and client organization members specified explicitly?	Yes, In the APS module induction session, every stakeholder had a chance to introduce him/herself and talk about their roles and responsibilities in an explicit manner. This is discussed in sections 4.2.1.1 and 4.3.1.1
C1e. Were project objectives and evaluation measures specified explicitly?	Yes, the module leader and the researcher clarified the aims, objectives, and assessment methods in the induction session of the module as well as in the first week of APS maths extra sessions. This is discussed in section 4.2.1.1
C1f. Were the data collection and analysis methods specified explicitly?	Yes, the researcher had the agreement of module leader for data collection and analysis. Methods of assessment was also approved by researcher's PhD supervisors.
P2. Principle of the cyclical process model	
C2a. Did the project follow the cyclical process model or justify any deviation from it?	Yes fully followed. The two cycles have been discussed in chapter 4. These cycles constitute two case studies each following the cyclical process model of the research. Sections 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.2.5 and sections 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5.

C2b. Did the researcher conduct an independent diagnosis of the organizational situation?	Yes, the diagnosis stage was based on academic methods and was performed independently by the researcher. This is discussed in sections 4.2.1 and 4.3.1. Table 30 presents the collective of issues diagnosed by the researcher.
C2c. Were the planned actions based explicitly on the results of the diagnosis?	Yes, the collection of identified issues was the basis of action planning and design. This was discussed in details in sections 4.2.1 and 4.3.2.
C2d. Were the planned actions implemented and evaluated?	Yes, in each cycle the planned actions were implemented and evaluated. This is discussed in full in sections 4.2.3, 4.2.4, 4.3.3 and 4.3.4.
C2e. Did the researcher reflect on the outcomes of the action research?	Yes, the reflection on the outcomes of the action research has been presented and discussed in learning stage of each cycles in sections 4.2.5 and 4.3.5.
C2f. Were this reflection followed by an explicit decision on whether or not to proceed through an additional process cycle?	Yes, since there was explicit improvement in the situation and the solution offered was more effective than traditional methods, it was decided to carry out this action research one more cycle. This is discussed in section 4.2.5.
C2g. were both the exit of the researcher and the conclusion of the project due to either the project objectives being met or some other clearly articulated justification?	Yes, the exit of researcher was based on met research objectives as well as improvement in the situation. The conclusion of the project was based on improvement in the concerned situation. This is discussed in section 4.3.5.
C2h. How was the independent diagnosis of the organizational situation conducted?	The independent diagnosis of the concerned situation was performed solely by the researcher and based on methods that the researcher analysed and selected. This is discussed in full in section 4.1, 4.2.1 and 4.3.1. Table 30 presents the issues diagnosed by the researcher.
C2i. Which instrumental theories did the researcher use?	VSM, SSM, SNA and dimensions of social capital were used as instrumental theories.
C2j. How were these theories selected?	The instrumental theories were selected based on their relevance to each aspect of the case through analysis of methods. This is discussed in literature review chapter.
C2k.How did these theories support the identification of the focal theory used to guide the changes?	There are commonalities between instrumental theories and focal theories e.g. VSM can be used as a tool/instrument for diagnosing the system and also as a focal theory to guide the method of change. This is discussed in the literature review chapter.
C2l. Post-operation, did the researcher reflect on the instrumental theories used and their suitability?	Yes, the learning stage of each cycle is when the researcher reflected on the use and suitability of the instrumental theories. These are discussed in sections 4.2.5 and 4.3.5.

P3. The principle of theory	
C3a. Were the project activities guided by a theory or set of theories?	Yes, the SCOR methodology was designed for this purpose. The activities were guided by a framework of theories as Part of F-M-A soft system account of action research.
C3b. Was the domain of investigation, and the specific problem setting, relevant and significant to the interests of the researcher's community of peers as well as the as well as the client?	The research gaps discussed in literature review chapter were both relevant and significant for the interest of researchers' community. In addition, solving the real life problem in this project was of great interest to the module leader as well as the business school.
C3c. Was an instrumental theory used to derive the causes of the observed problem?	Yes, VSM was used as an instrumental theory for diagnosis. SNA and ethnography were used as tools to search for the causes of the issues. These are discussed in sections 4.1, 4.2.1 and 4.3.1.
C3d. Did the planned actions follow from this instrumental theory?	Yes, the way to address aspects of the problems were devised based on the theories. This is discussed in sections 4.2.2 and 4.3.2.
C3e. Was the focal theory used to evaluate the outcomes of the operations/actions?	Yes, VSM is used for performance evaluation and SNA is used for changes occurred in the students' network. These are discussed in sections 4.2.4 and 4.3.4.
C3f. Did a focal theory emerge from the situation or during the problem diagnosis?	The assessment of the situation demanded the use of effective focal theories. Literature review suggested VSM and SNA as a combination to be the focal theories. There was a framework of theories which was found relevant during problem diagnosis.
C3g. Was this focal theory acceptable to both client and researcher?	Yes, the researcher discussed thoroughly with the module leader about the application of theories through plan of actions and agreement reached. This is discussed in section 4.2.1.2.1.2 (system 4's decisions).
C3h.What role did instrumental and focal theories play with respect to the diagnosis and the action planning?	Instrumental theories were used for problem diagnosis and for explaining the concerning issues. Focal theories were used to provide the rationale behind and the drive for the systemic change remedies.
C3i. Were these theories evaluated for their applicability to the organizational context, considering current organizational practices?	Yes, VSM was evaluated thoroughly based on several measures and compared with other methods. This is discussed in literature review as well as in section 4.2.1.2.1.2 (system 4's decisions).
C3j. Did both the researcher and the client undertake this evaluation?	Yes, the client did an evaluation from her own perspective and the researcher had a separate assessment of the situation. When we met and discussed the two evaluation were in the same line suggesting the same issues. There is a discussion from client perspective in section 4.2.1.2.1.2 (system 4's decisions) From researcher angle, literature

	review was performed to evaluate the suitability of focal and instrumental theories.
C3k. Were theoretical explanations for the current organizational problem situation evaluated and reflected upon?	Yes, the researcher and the module leader assessed and reflected on the theoretical perspectives of the concerned situation in the meeting related to planning stage. This is discussed in full in sections 4.1, 4.1.3, 4.2.1 and 4.3.1.
C3l. Did the researcher reflect on the focal theory used and its ability to predict the change outcomes?	Yes, the reflections led to an understanding about how focal theories can enable the researcher to plan more effectively and predict the change outcomes. This is discussed in sections 4.2.5 and 4.3.5.
P4. The principle of change through action	
C4a. Were both the researcher and client motivated to improve the situation?	Yes, the researcher meant to write a PhD thesis and the client wanted to have the problematic issue resolved.
C4b. Were the problem and its hypothesized cause(s) specified as a result of the diagnosis?	Yes, the collection of issues was reflected upon and concluded in the diagnosis stage of this research. There are discussed in sections 4.1.3, 4.2.1, 4.3.1 and specified in Table 30.
C4c. Were the planned actions designed to address the hypothesized causes?	Yes, the causes of the problem were central when actions were planned. This is discussed in sections 4.2.2, 4.3.2.
C4d. Did the client approve the planned actions before they were implemented?	Yes, the researcher and the module leader discussed and approved the planned actions. An alternative was also considered if the main plan would have faced challenges. These are discussed in sections 4.2.1.1, 4.2.2.1.1, 4.3.1.1. and 4.3.2.1.
C4e. Was the organization situation assessed comprehensively both before and after the actions/operation?	Yes, the assessment of organisational situation was performed based on impacts of planned actions on change in performance, change in skills levels, change in maths knowledge network and emergence of strategies. These are discussed in sections 4.1, 4.2.4 and 4.3.4.
C4f. Were the timing and nature of the actions taken clearly and completely documented?	Yes, this PhD thesis precisely and fully documented the timing and nature of actions in both cycles.
P5. The principle of learning through reflection	
C5a. Did the researcher provide progress reports to the client and organizational members?	Yes, there were regular meeting in place to discuss and provide report to module leader as well as to researcher's PhD supervisors. These are discussed in sections 4.2.2.1 and 4.2.5.
C5b. Did both the researcher and the client reflect upon the outcomes of the project?	Yes, the final meeting of each cycle was for teaching/tutorial team and module leader to collectively reflect on the outcomes of the project/module. These are discussed in sections 4.2.2.1, 4.2.5, 4.3.5.

C5c. Were the research activities and outcomes reported clearly and completely?	Yes, the activities that carried out in the action research as well as the outcomes were reported in a concisely and fully. These are discussed in sections 4.2.2.1, 4.2.5, 4.3.5.
C5d. Were the results considered in terms of implications for further action in this situation?	Yes, after first cycle, it was decided to carry out the action research one more time in the next academic year. This is discussed in section 4.3.5.
C5e. Were the results considered in terms of implications for action to be taken in related research domains?	Yes, the researcher considered using the SCOR methodology for action research in other contexts when opportunities arise. discussed in section 6.4.
C5f. Were the results considered in terms of implications for the research community (general knowledge, informing/re-informing theory?	Yes, these are related to contributions to knowledge and practice and are discussed in sections 6.1, and 6.2.
C5g. Were the results considered in terms of the general applicability of CAR?	Yes, the researcher has considered to publish this method in academic journals of action research.

Table 68: Meeting Principles and Criteria of Canonical Operational Research in SCOR Methodology of this Research

5.5.5. Transferability of the Systemic Action/Operational Research

In evaluating systemic action/operational research, validity becomes important when methodological knowledge is going to be produced and used outside the immediate research contexts (Midgley et al., 2013). Similar to other soft-OR approaches, the purpose of the SCOR multi-methodology of this thesis is not to provide 'testable results' but rather to offer deeper insights and better understanding (Ackermann, 2012). This issue provokes thinking about the problem of impact assessment and the concerns regarding transferability of the methods. Vidal (2004) reveals a lack of consensus over how to assess soft-OR studies. Checkland (2000) emphasises that the requisite condition for drawing a conclusion on transferability is decades of research by means of multiple and varied cases studies. In this sense, the typical length of a PhD programme in the UK is limited to four years. This timespan does not allow for building a multi-methodology that can be established fully through several empirical case studies in order to claim transferability. The researcher's goal was therefore modest, aiming to develop and test a soft-OR multi-methodology with 'transferability potentials'. In addition, transferability across contexts was limited during this PhD action research. As Pawson (2006) states, participatory research collaborations, establishing mutual understanding and developing agreements that can influence organisational policies are important but time consuming and, by nature, situational. Therefore, in the two cycles of this action/operation research, the researcher could only 'test' the multi-methodology through arranging two contextual case studies in a single business school. The evaluation and assessment of the two case studies offer other scholars the knowledge, insights and understandings that can be ‘transferred’, adopted or reused. As Tracy (2012) states, other scholars or practitioners who use this multi-methodology would have to reflect on its implementation and evaluation for their specific situational contexts.

Chapter 6: Thesis Conclusions

6.0. Introduction

This research project commenced after a call for a solution with which to improve students' skills development and performance in maths. The issues surfaced because of increasing rates of performance failure for three consecutive years in an undergraduate academic module (APS-Maths), in a UK business school (BSUKU). In order to deal with the complexity of the problems, and informed by a literature review to develop the framework of ideas (focal and instrumental theories), a soft-OR multi-methodological framework was designed and implemented for this research. The outcomes were assessed in terms of improvements in students' performance. The reflection on the research project provided valuable insights into, and learning about, the original questions which motivated this research, as illustrated in the following sections.

6.1. Answers to Research Questions

At the beginning of the research journey towards designing the SCOR multi-methodology and its systemic solution, six research questions were developed which are answered in the present section.

6.1.1. Answer to Research Question 1

How can middle-ranked UK business schools strengthen their ability to understand and manage the complexities involved in knowledge sharing processes (for student learning) using a systemic multi-methodology?

In the case of BSUKU, the answer to this question was mainly through investigations in the area of application (Section 4.1) and the diagnosis stage (Section 4.2.1 and Section 4.3.1) of this research. The in-depth exploration and analysis in these stages led to the identification of conditions and the clear recognition of key problems affecting students' performance. Table 30 presents a summary of collective issues found at the diagnosis stage. As CAR (hard-OR) and F-M-A (soft-OR), along with VSM and SNA, were combined in this multi-methodology, each of the analyses resulting from these stages provided specific (and complementary) lessons and learning. Very importantly, the research offered valuable insights into the importance of learners' self-organisation at the personal and team level. The research project contributed to demonstrating to the module team – including the module leader in BSUKU – better ways of managing the complexities involved in the processes of knowledge sharing and students' learning through better design. It was understood more clearly how guided self-organisation influences the learning and affects the performance. As a result, the BSUKU could appreciate the efforts needed in order to guide the self-organisation among students at individual and team levels in the particular module of APS-Maths, where there were clearly issues obstructing students' effective knowledge sharing and learning. The lessons learned can be thought-provoking for other middle-ranked business schools in the UK that aim to advance their understanding in order to manage the complexities of learners' knowledge sharing, learning processes and performance improvement.

6.1.2. Answer to Research Question 2

How can middle-ranked UK business schools enhance learners' skills development and performance improvement using a systemic multi-methodology?

For the BSUKU as a middle-ranked business school, this question was answered through two cycles of action research presented in Chapter 4, implementing a solution for collective knowledge sharing and collaborative experiential learning among students in the module of APS-Maths. Notably, the action planning stage suggested in this research followed an in-depth diagnosis of the situation and its outcomes, which proved to be very useful and resulted in more relevant actions plans. In this vein, the use of domains of viable knowledge for the purpose of skills development and performance improvement shaped a more structured bottom-up approach in which learners took the ownership and regulation/control of their maths skills problems and of the methods/solutions to said problems. This bottom-up approach promoted self-organisation at the individual and team level and led to higher level of skills development, learning and performance improvement. This proved that, at least in the present exploratory case study, by guiding/enhancing the students' self-organisation processes for knowledge sharing and learning, BSUKU did manage to enhance learners' maths skills development and to improve their academic performance in the first year of their university degree. This was facilitated through a series of experiential learning activities by the researcher.

Although it is difficult for higher education institutions to let go of hierarchical teacher-centred solutions (Buck and Akerson, 2016; Estes, 2004), this research suggests that a genuinely learners-centred bottom up approach can lead to a more effective way of learning management, skills development and performance improvement, rather than just management of the teaching. This is also in agreement with Sakata (2019), Noble et al. (2019), and Kitta and Tilya (2018). It is therefore recommended to foster more bottom-up approaches that promote self-organisation, such as the one in this systemic multi-methodology, to improve students' performance.

6.1.3. Answer to Research Question 3

How can a systemic multi-methodology facilitate the design and development of effective knowledge sharing structures and processes?

In the case of the APS-Maths project at the BSUKU, the multi-methodology of this research helped in several ways towards designing the knowledge sharing structures and processes. At the diagnosis stage (Section 4.2.1), key issues were discovered based on viable system diagnosis. The VSM diagnosis in this stage revealed missing structural links and misalignment between issues and solutions. For example, it revealed missing links between streams of highly-skilled and low-skilled students and missed opportunities for knowledge sharing among them.

The qualitative SNA, through ethnography, revealed differences in the governing processes of learning and knowledge sharing. The design and development of more effective knowledge sharing structures and processes in the action design stage (Section 4.2.2) were informed by the results of the diagnosis stage. Using domains of viable knowledge was effective in appreciating the roles, functions and structure of the knowledge sharing processes at the learners level, thus creating the space and environment for self-organisation. These domains, which were originally devised for knowledge management by Achterbergh and Vriens (2002), were adapted for the context of learning in the classroom (see Section 4.2.2.1.3, Table 35). The researcher then used these context-orientated domains and created a method note for learners (see Appendix 2). The method note was prepared to facilitate learners' understanding regarding the basics of the roles, functions and structures needed for knowledge sharing and collaborative learning in their teams and in the knowledge network. During the course of extra maths sessions in the knowledge network, the learners were given enough freedom to suggest and to reform such functions and structures, if they felt it was useful.

In order to manage knowledge sharing/learning processes in teams and in the learning network, three dimensions of social capital (cognitive, relational and structural) were considered. This resulted in the suggestion of an optimised skills-mix, which guided the process of self-organisation within the teams. This was through facilitating teams' purposeful social interactions and communications, to enhance the process of collective knowledge sharing and collaborative experiential learning.

Moreover, in order to measure how effective the solution has been in terms of facilitative processes and structures of knowledge sharing and learning, the researcher used performance measurement concepts from both the viable system model and SNA. Results provided in Section 4.2.2, Section 4.2.4.2.3, Section 4.2.5, Section 4.3.2, Section 4.3.4.3 and Section 4.3.5 showed that these performance measures are indicative of the effectiveness of the solution.

6.1.4. Answer to Research Question 4

How can a systemic multi-methodology assist in uncovering and reducing structural fragmentations in a knowledge sharing network?

With reference to the case study of the present research, the answer to this question lies in the diagnosis stage (Section 4.2.1.2.4.1 and Section 4.3.1.2.2.1), the action planning stage (Section 4.2.2.1.2 and Section 4.3.2.1.2) and the evaluation stage (Section 4.2.4 and Section 4.3.4.3). The knowledge network was suffering from structural disconnections among students with different skills levels. This was a barrier for knowledge sharing between highly-skilled and low-skilled students. As a result, an operational plan was designed based on students' skills-mix in teams to reduce the disconnections and to promote the effective/purposeful interactions, which in turn could guide/facilitate the self-organisation process. Implementing the skills-mix plan by assembling teams within the extra maths sessions (operational plan 3) was successful and led to more heterogeneity in the structure of students' knowledge network (Section 4.2.4.2.3 and Section 4.3.4.3). The social network analysis of students' knowledge network at the end of the experience proved that structural fragmentation has been reduced and that the knowledge sharing network was heterogeneous with a healthy degree of cohesion. Overall, SNA was useful for depicting the connectivity, power influence and prominence in the learning/knowledge network. Moreover, the VSM was beneficial in the management of the knowledge network by providing criteria with which to design a context for more viable interactions/communication loops and regulations. This study proved that VSM diagnosis and SNA are complementary methods when it comes to addressing and managing structural fragmentation.

6.1.5. Answer to Research Question 5

How social network ties can shape a team's knowledge sharing skills and capabilities in a knowledge network?

Figure 40 in Section 4.2.4.2.3 and Figure 57 in Section 4.3.4.3 reveal the strength of ties in pairs of students (the width of the link between the two) in the APS-Maths knowledge network. These ties were underpinned by purposeful cycles of communications and interactions. The tie strength was based on the number of times each learner found another learner in the team helpful to himself/herself, in terms of sharing knowledge and collaborative support in experiential learning. Weaker ties showed the communications/interactions, and stronger ties illustrated effectiveness of the communications in terms of knowledge sharing and success in maths problem solving. This is particularly important since the presence and strength of social network ties is indicative of the team's process of self-organisation towards its objectives/goals. In effect, in order to shape the team's knowledge sharing skills through ties, two processes occurred within the teams. One process relied on continuous experience of sensing the mistakes of peers in solving maths questions and sharing knowledge to rectify them (i.e. single-loop learning) at the team level. From the other side, the learners were not bound to stay in the same team during all sessions. This was partially due to their voluntary attendance. In addition, they gradually became aware of who were the best helpers in the network. Students could then form/reform their teams of five (with a skills-mix ratio of 1:4) in an organic way, e.g. by asking a particular highly-skilled student to join their team. Hence, there were constant opportunities for students to manage their different team situations. This, on its own, shaped new scenarios for the team's self-organisation. Experience in managing such different team situations was then developmental in terms of skills for managing the team towards collective knowledge sharing/collaborative experiential learning. Hence, the next process for development of knowledge sharing skills through ties involved the continuous experiential learning cycles on meta-systemic tasks. These meta-systemic tasks comprised detecting mistakes in the team's goal decisions, team-working rules, communicating such information in the team, strategising on the team's further learning development, reaching a consensus and modifying said consensus (i.e. double-loop learning) in a rather self-organised and reflective way within the teams. These meta-systemic roles were developed based on domains of viable knowledge (see Section 4.2.2.1.3, Table 35) and were implemented through method notes (see Appendix 2) in the extra maths sessions. The two processes mentioned above were dependent on each other. It was the continuous transitions from single-loop learning to double-loop learning that led to the overall skills development at the individual and team level. Since team members were not fixed in each of the sessions (though the skills-mix ratio was fixed) the organic skills-mix of teams could also enhance the skills development while simultaneously improving the performance at the network level. Hence, the presence and strength of ties played a crucial role in the process of self-organisation towards objectives/goals at both the team and network level.

While this action research provided some evidence for network ties and how they shape the team's knowledge sharing skills, more research is required to shed further light on whether network structures for a team's skills development can be separated based on ties for primary tasks and ties for meta-systemic tasks, e.g. how those who only do the primary tasks and never take part in the team's meta-systemic tasks develop their respective skills in contrast with those who are actively involved in both. This will give us an even deeper understanding of what else happens within a team's self-organisation of learning processes.

6.1.6. Answer to Research Question 6

How can VSM theory support network cohesion in a knowledge sharing network?

Fragmentation and structural disconnections in the network can be revealed through social network analysis. However, SNA is an analytical tool and not a management model/approach. On the other hand, VSM provides a more consistent and comprehensive theory, as well as a tool for systemic management. With reference to this research, viable system diagnosis revealed the issues including the misalignment/disconnection between management of teaching activities and management of learning activities (discussed in Section 4.2.1.2.2, system 3 and 3* issues). It also uncovered the missing links between streams of highly-skilled and low-skilled students due to the streaming and timetabling strategy (discussed in Section 4.2.1.2.2, system 1 issues). Network cohesion is defined based on number of communication/interaction ties among learners, and evidently such knowledge sharing ties were missing/not-very-active among students at the beginning. The actions designed and implemented in the two case studies of this research at the learners level were a bottom-up response to such issues, facilitating the development of the students' team/network ties, and guiding the self-organisation within the teams and among the teams at the knowledge network level. Hence, it is pertinent to say that guided self-organisation increased the cohesion in the network. In this research, goal setting as a self-organised process among team members was carried out by implementing the first two domains of viable knowledge. This self-organised process (in system 1) further motivated the learners to preserve the developmental experiences of knowledge sharing and learning/practising activities (reconfirming Day and Sin, 2011). It also encouraged them to implement the other domains of viable knowledge e.g. regulating the team learning processes towards network goal/identity (as with the role of system 3), hence supporting the cohesion in the knowledge network. Notably, the collaborations in the team's learning processes and joint task undertakings supported students with different skills in becoming connected to each other in the team and in the knowledge network. Since students with different skills levels were following different norms for their maths learning (discussed in detail in Section 4.2.1.2.3), such connections/interactions helped them to share and to experience such different norms of maths learning processes and in turn to decide on the best norms to follow as a team. Creating/increasing interactions and communications loops, i.e. generating and strengthening ties among learners (role of system 2) as well as regulating the required loops for managing resources and performance and the balance between the two (role of system 3), did increase the network cohesion. Managing resources was about managing knowledge/cognitive capitals (e.g. different levels of knowledge/skills), relations (e.g. the interactions among learners) and structures (e.g. teams' skills-mix compositions). Performance was related to learning outcomes and skills development. The innovative strategies that students brainstormed and agreed upon (through increased interactions) in order to better manage their teams in terms of skills development (role of system 4) in fact strengthened the ties among them in their knowledge network. The above-mentioned are the functions of system 2, system 3 and system 4 of the VSM. These are all fully clarified in the domains of viable knowledge provided in Section 2.3.3.3 (Table 9) and the equivalent of that in the context of knowledge sharing/learning in Section 4.2.2.1.3 (Table 35).

Furthermore, important for creating cohesion in the knowledge sharing network is variety engineering. As presented in Table 63 (discussed in Section 4.3.4.4), some of the strategies formulated in the extra maths sessions were variety engineering strategies (amplification, attenuation, the balance and maintenance) in the teams and in the network. While VSM is proficient in devising such strategies and creating network cohesion, SNA as an analytical tool can only reveal part of such cohesion. This is because SNA relies merely on the ties among learners and not on the contents of ties where strategies might reside.

6.2 Contribution to Knowledge

An indispensable part of a doctoral thesis is the emergence/creation of new knowledge (Tracy, 2012). The contribution to knowledge in this research relates to the processes and mechanisms within a learning context, which enable a system to self-organise and to reproduce itself. In the context of learning, these mechanisms facilitate students' skills development and performance improvement (within an educational institution). This research, therefore, offers relevant insights into the management of students' learning.

First contribution:

> **Guided self-organisation is a more effective approach for skills development and offers better results than traditional methods.**

This action research shows that learners' skills emerged more effectively when essential mechanisms to guide the learners' self-organisation processes were in place and facilitated knowledge sharing and learning, as explained below.

In the first week of the action research, the provision of a basic introduction to the concept of VSM (as the theory of effectiveness) and Achterbergh and Vriens' (2002) domains of viable knowledge (as per method note in Appendix 2) shaped a shared mental model and collective understanding of the maths knowledge network's governance and identity. This shared understanding emerged and guided the subsequent self-organising processes.

In effect, the first two domains of viable knowledge (as per method note in Appendix 2, handed in to the learners in the first week) facilitated the development of a shared language and the rest of those domains guided the organisation/management of the network, in relation to the structure and mechanisms of the team's effective knowledge sharing. The note also permitted the learners to become aware of and reach a common understanding about their maths knowledge network by clarifying goals of the teams as well as reaching an agreement on the maths knowledge network's identity. It also allowed them to perceive how the teams can co-evolve together in the knowledge network through knowledge sharing among said teams. As soon as this shared understanding emerged, more and more effective organisation appeared in teams and in the knowledge network.

Hence, there was more self-organisation with less conflict due to clarity on key tasks/roles, joint undertakings and the new means of interactions. The result was purposeful communications for knowledge sharing, effective synergies/collaborations, and a heterogeneously-distributed network without a top-down control.

Hence, the knowledge sharing within the network became more efficient through collaboration and cooperation. Changes were manifested in collaborative knowledge sharing processes, and in development of internal strategies towards skills development and performance improvement in the learners' knowledge network. In such a context, the practice of carrying out the regulative processes was evident in each session through feedback reports containing the agenda/strategies for making knowledge sharing processes topic-specific and focused on communications/interactions, in relation to the problems at hand.

The researcher recognised that self-organised knowledge sharing tasks and collaborative learning processes have key roles in how skills and capabilities are developed. This coincides with Helfat and Winter (2011), Teece (2007) and Zollo and Winter (2002). In addition, learners found out in such processes of skills development that in order to create and complete the feedback loop of knowledge sharing and collaborative learning/practising, they need to attempt to solve the maths problems by themselves first (i.e. personal self-organisation), based on which they would then be able to ask for help from others, discuss and reflect (i.e. team self-organisation).

In addition, and in line with Espejo (2015), this research established that it is through gaining experience in the process of continuous transitions from Argyris and Schön's (1978) single-loop learning to Argyris and Schön's (1978) double-loop learning in circular loops, that skills and capabilities at individual, team and organisation levels are developed and strengthened.

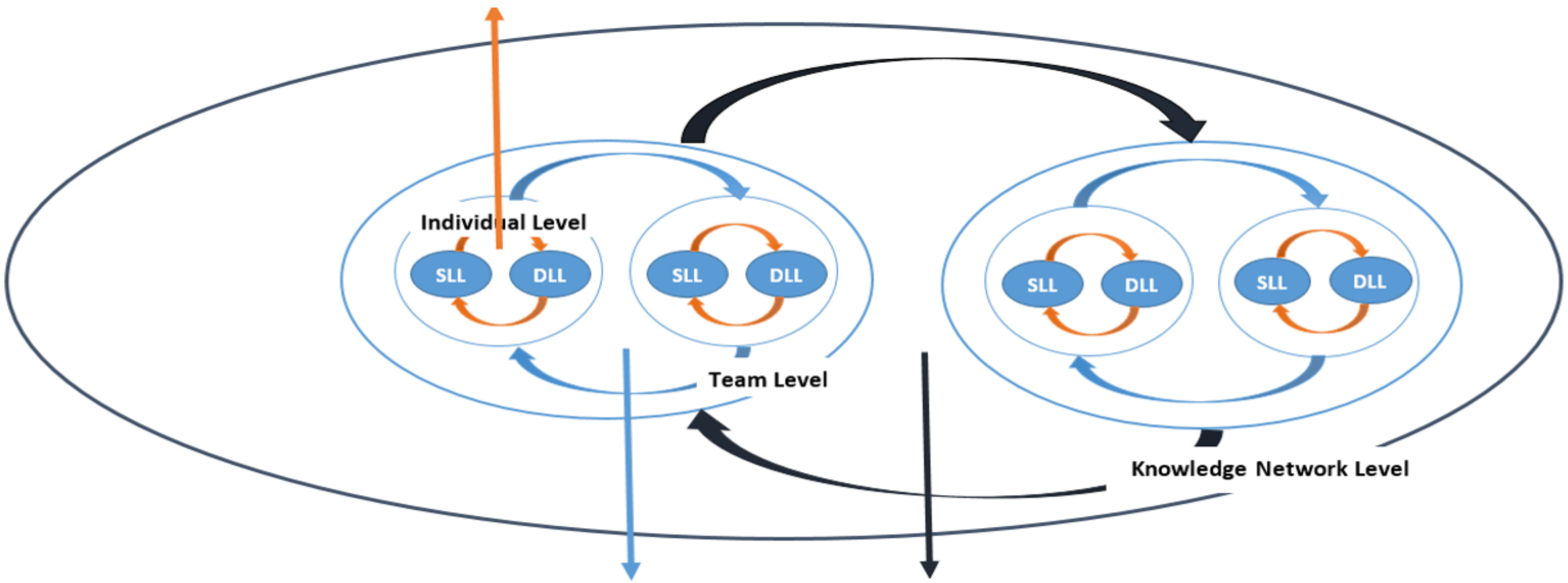
- **First-order learning:** A learning process within which continuous Kolb's (1984) experiential learning cycles on **primary tasks** occurred.
- **Second-order learning:** A learning process within which continuous Kolb's (1984) experiential learning cycles on **meta-systemic tasks** occurred.

Continuous transitions from single-loop learning (where continuous experiential learning cycles on primary tasks occur), to double loop learning (where continuous experiential learning cycles on meta-systemic tasks occur), lead to skill development and performance improvement.

Skills development and performance improvement in Individual level:

Primary tasks: Solving the maths questions, sensing the mistakes and rectifying them personally.

Meta-systemic tasks: Detecting the mistakes on the decisions about individual's learning goal and modifying them personally.



Skills development and performance improvement in team level:

Primary tasks: Sensing the mistakes of peers in solving the maths questions, and sharing knowledge to rectify them within the team.

Meta-systemic tasks: Detecting the mistakes on the decisions about team's learning goal and team-working rules and then modifying them together in team.

Skills development and performance improvement in network level:

Primary tasks: Sensing the issues/mistakes of teams in maths problem solving activities and sharing knowledge together to rectify them within the network.

Meta-systemic tasks: Detecting the mistakes on the decisions about network's learning goal, norms, ethos, and policies and then reaching consensus to modify them.

Figure 58: Recursive Performance: Individual, Team and Network Levels

Guided self-organisation at each level in fact increased the accumulation of such experience as well as the number of transitions from one state to another in the processes of learning. Performing the agreed tasks in the extra maths sessions (individually, in teams and in the network) was found to act as a proxy for first-order and second-order learning and such learning enabled the development of primary and meta-systemic skills/capability, respectively. This was a guided self-organised process. Skills development started from operational ones and then expanded to meta-systemic skills/capabilities and following this it fed back again to operational skills in a circular developmental loop. Evidently, these developmental loops were recursive, hence performance at each of the levels was improved recursively. To understand these recursive performances, Figure 58 illustrates a typical knowledge network model. For simplicity in explaining the recursive skills development and performance improvement, a team is considered to have two members and the network to include two teams. Bigger teams and larger networks follow similar recursive principles. This is how the first-order learning and second-order learning happened in VSM terms and provided empirical evidence for epistemological and methodological dependency of the two, at least in the context of classroom education.

An important aspect of the self-organisation that was noticed in both cycles of action research was the need for guidance. Espejo (2015) asserts that guided self-organisation is needed for creating a learning organisation. This was through, for example, arranging the teams' skill-mix, which in turn improved the capacity of the teams and subsequently the capacity of the network to act autonomously. It reaffirmed that the right learners are in the right places to collaborate in knowledge sharing, learning and practice. Ay et al. (2012) consider the existence and maximisation of predictive information/knowledge as of a vehicle for self-organisation. Here in this research, the ratio of 1:4 in teams (mentioned above) enabled the process of teams' dynamics to be steered towards the goal/desired outcome (i.e. skills development and performance improvement) and in the direction of maintaining the identity of the maths knowledge network. At the network level, the researcher also guided the self-organisation by motivating the teams to broker knowledge from other teams, which could increase the synergy for further maths knowledge sharing in the knowledge network. This was carried out through throwing thought-provoking questions into the discussions that were relevant to both primary tasks and meta-systemic tasks.

The researcher used students' overall attendance rates as the logic of team composition (predictive information) so as to promote the effective management of their social capital. Notably, this logic of team composition should not be misunderstood as high attendance for everyone. In other words, the logic of team composition does not say that the same students were attending the sessions based on a particular rate. In fact, students were attending organically and voluntarily. In effect, this means that overall, in each session, there was a sufficient number of highly-skilled students and enough low-skilled students in order to assemble teams based on the ratio of 1:4. The ratio of 1:4 for highly-skilled to low-skilled students was not only helpful for knowledge sharing but was also as a measure for guiding self-organisation in teams. The presence and knowledge sharing/contribution of a highly-skilled student among the other four learners (who were less skilled in maths) was such a measure. This also helped to reduce the conflicts/frictions among team members with their varied methods of solving the maths questions and to increase their understanding about conflicting methods of maths problem solving through discussions/synergy (since the highly-skilled student could effectively assess those methods and explain to others which method is better and why). In addition, the skills-mix allowed the emergence and development of team goals. This again was because the highly-skilled student could share with the other four teammates his/her differing personal learning governance practice, including the need for a goal to be achieved. Becoming goal-orientated was therefore guiding/facilitating the team self-organisation process. Hence, guided self-organisation is a better description of what was performed in the action/operations of this research.

Further, from a knowledge network perspective, since the cohesion and density of the network increased, there remained no doubts that the network became more viable. This created a distinctive context where feasible ways of meta-systemic skills and capacity development for coping with learning complexities and improving learning performance emerged. This was not the case for those who did not participate in the extra maths sessions (in both cycles). Hence, this research agrees with Gershenson and Rosenblueth (2012), who state that “a self-organizing method is scalable, adapting to the complexity of a scenario and exploiting its maximum capacity”. Likewise, this action research suggests that implementing self-organisation mechanisms such as those mentioned above can lead to results that are closer to optimal learning performance.

Similar to Polani et al. (2013), guided self-organisation in the knowledge network of this research had at least three characteristics, namely:

- First, there was an increase in the re-organisation of forms and/or functionalities, since learners were free to reform the functional aspects in their teams.

- Second, there was not explicit guidance from any external agent for the local knowledge sharing/collaborations.
- Third, task-dependent goals were made by the team and in line with task-dependent limitations/constraints. This is part of the system's self-organising behaviour.

Overall, the findings of this action research suggest that self-organisation in a knowledge sharing network has the following features:

A) There is shared understanding of the viability of the knowledge network.
B) Provision of critical task specifications is minimal. Reliance is on teamwork/collaborations and there is common ownership of the results.
C) Effective knowledge sharing networks are bound by small teams with a diverse skills-mix and flexibility.
D) Tasks might be undertaken jointly, hence requiring more interactions.
E) Mistakes can be noticed at their origin/source and can be resolved there.
F) Knowledge/information flows through communications.
G) Feedback loops communicate the effectiveness of individuals, teams and networks.
H) Developing strategies for survival is an ongoing process and is based on continuous cycles of learning and experiencing.
I) Those who operationalise a plan are more likely to provide the most effective strategies.
J) Autonomy emerges based on self-organised learning.

Moreover, knowledge network in this research is considered as a self-organising system that moved away from entropy. Since there were knowledge varieties in the knowledge network, entropy was restricted. The system became negentropic through guided self-organisation in its proxy, i.e. teams. Teams were loaded with energy and information. Since individual team members were not bound to stay in one particular team in every session, information spread in the network in an organic way. Within the knowledge network, this information was translated in order to become relevant and applicable. New knowledge was generated when the translated information was communicated with others as they interacted and collaborated in teams. Learners understood said knowledge in relation to the system and in relation to the task at hand. This meant that the energy/information was absorbed more effectively in the collaborative learning/practising processes of the system and was represented in terms of skills developed. This system, according to Von Foerster (2003), was able to enhance its own order internally.

Second contribution:

Guided self-organisation creates an effective context for autopoiesis.

This action research reveals that a learning/knowledge sharing network becomes autopoietic, provided there is an effective context in place. Such effective settings can be created through guided self-organisation, as explained next.

In both cycles of this action research, the learning/knowledge sharing system appeared to reproduce itself. Initially students asked the researcher to facilitate the same types of sessions for their accounting and finance module. As this was not possible for the researcher, one of the highly-skilled students offered to facilitate extra sessions for knowledge sharing and collaborative experiential learning for that module. As soon as the timings/space for their gatherings were arranged, they gathered and implemented the same knowledge sharing/learning structures and processes that they had found, through experience, to be effective in extra maths sessions, for their extra accounting and finance sessions. In addition, similar to the use of a Facebook group for maths knowledge sharing, they used their Facebook group to announce/remind people of the timings and locations of accounting practice sessions. The researcher attended these sessions and witnessed that their approach for knowledge sharing/learning towards skills development was reproduced from those in the extra maths sessions. It was evident that through participation and collaboration in extra maths sessions, the students' observations and practice showed them that the maths knowledge network is serving its purpose and identity. Such evidence provided enough motivation for them to think of and to use the same methods/mechanisms/processes for developing the skills required in the accounting and finance module, i.e. reproducing their learning/knowledge sharing system in a self-organised way.

The identity of the extra maths session as a system was "to create a knowledge network for skills development and effective performance" and this identity remained unchanged/untouched for the extra accounting/finance sessions. In this arena, Beer (1980) asserts that a social system is autopoietic as long as it has an identity and it keeps that identity alive. This research understands the learner's knowledge network as a social system and reconfirms that it was an autopoietic system though upholding its identity. It is important to mention that the identity of a social system is geared by understanding its structures and the way it organises its dynamic processes and mechanisms. In this research, the learners could understand what their knowledge network does, who does it, whom they do it for, and who/what is involved. This shared comprehension developed their understanding about what their knowledge network is, and hence its identity. This is in line with Espejo et al. (1999), who suggest that the surest way to establish a system's identity (i.e. what the system is) is to figure out what the system actually does.

In this arena, steering/guiding the dynamics of the system towards its goal and identity is a guided self-organisation process which facilitates the system to achieve the outcomes sought after or to realise the desired systems' configurations. In this research, such a process happened without any explicit guidance/order from an external agent to the learning network. Instead, teams decided their learning goals depending on the tasks/activities at hand with due consideration paid to teams' knowledge constraints. For instance, when the mathematical concepts behind the questions to be solved were difficult to absorb, one team decided to answer five questions instead of eight, but to make sure everyone with any level of maths knowledge in the team fully understood the approach and the solutions of those five questions. Coinciding with Polani et al. (2013), this is a characteristic of guided self-organisation in a knowledge network. Said goal-constraint dependency also showed that the system has self-defining boundaries and that the internal relations and dynamics of the system generate the elements of the boundaries. The notion that the system's identity is geared by its structures and its way of organisation is in accordance with Maturana and Varela (1980), who assert that it is the structure and organisation of the system that helps the system to reproduce itself and that such a process is contained within the system's boundaries. Their definition of autopoietic system is self-explanatory in this regard (see footnote)[2].

The interactions and recursive communication cycles in teams and in the network were the key factors for autopoiesis to emerge. In effect, such communication cycles were inherent in the continuous processes of maths knowledge sharing and collaborative learning, aiming at skills development and performance improvement (reconfirming Malekovic and Schatten,

[2] Maturana and Varela (1980) mention that: "An autopoietic machine [system] is a machine [system] organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network" (pp. 78-79).

2008). The question of why/how interactions could relate to collaborations can also be explained. Communication/social interactions do structurally couple a social agent with others by means of language. While system 2 of the VSM was responsible for easing the collaborations and for resolving the competitions/conflict among teams in the knowledge network, the sense of cooperation and collaboration was developed within teams and among teams in the knowledge network, based on basic feelings/moods such as fairness, mutual respect, friendliness, trust and acceptance. These feelings (which according to Maturana, and Verden-Zoller (2008) are predominantly features of love) were opposite to competition, rivalry, or viciousness. As discussed in Section 2.3.3.2.6, competitive relations/interactions are not indicative of self-organisation. On the other hand, collaboration/cooperation as well as communications/social interactions facilitate social agents to exist and maintain their collective existence and are indicative of self-organisation. These authors suggest that such a natural/organic way of cooperation/collaboration is underpinned by biology of love and results in enhanced social consciousness. This illustrates a higher level of perception and is in line with Sice et al. (2013), who state that autopoiesis emerges in a fostered environment underpinned by active increase in awareness, avoiding fragmentation of experience and the use of discursive language for promoting creativity.

Overall, the researcher considers that this action research (soft-OR), underpinned by organisational viability theory (VSM), has provided interesting connections between guided self-organisation, knowledge sharing, collaborative experiential learning as well as skills/capability development, and performance improvement. The soft-OR approach of this research and the two case study applications open an avenue through which to explore and examine how business schools such as the BSUKU are able to diagnose, design and implement effective methods in order to support learners' knowledge networks with the aim of enhancing the institutional effectiveness through more guided self-organisations processes.

With reference to the answers to the research questions and the two contributions mentioned above, this research provides insights into, and understanding of, the practice of learning management. Contributions to practice are discussed in the next section.

6.3 Contributions to Practice

Reflecting on the area of application/concern (Section 4.3.1), the research questions and the answers provided (Section 6.1.1, Section 6.1.2, Section 6.1.3, Section 6.1.4, Section 6.1.5, and

Section 6.1.6) in this research contribute to the practice of maths teaching and learning in the UK higher education institutions. They provide a soft-OR multi-methodology that facilitates a deep understanding of the management of knowledge sharing practices and students' learning processes, through six stages of assessing the area of application/concerns, diagnosis, action planning, implementing the plan, evaluating the outcomes and reflection/learning. This research provided an effective approach to tackle the complexities involved in the process of maths learning as well as the management of maths learning. In agreement with Frade and Borges (2006), maths knowledge in this research is considered as an interplay of tacit and explicit knowledge. In particular, the use of viable system diagnosis made it possible to find the mismatch between the type of knowledge and the ways of sharing it with students. The researcher discovered this by going deeper into the learning processes and by understanding them better rather than by examining the teaching structures only (see Section 4.2.1.2.2). Having stated this important point, however, the researcher is concerned with the '*level of awareness'* that module leaders/lecturers or even sometimes learning design analysts (with their capacity/roles in system 2) have about typologies of knowledge and how each type requires differing solutions for knowledge sharing/teaching. Here, a second-order cybernetician might be able to possibly activate such *awareness* through being part of the system of learning management and via *observing the observed*. However, this activation still depends on the level and extent to which the observer (as a system) interacts with the observed system and how much the institutions are ready to accept the issues and alternative solutions. For those schools that teach maths as a pure field of study, in general, they are organically aware of how to share it with students through encouraging the interactions and the continuous experiential practice which covers the dynamic interplay between the tacit and explicit nature of maths knowledge. Yet, when it comes to sharing maths knowledge in a business school, e.g. where module leaders/managers/lecturers' main speciality is not pure maths, but rather the application of maths in other fields, then spotting the difference between types of knowledge is not very easy. Hence, less effective knowledge sharing mechanisms might be applied. In this arena, it is recommended to involve or at least consult with a pure maths lecturer about the superior ways of sharing maths knowledge as a default check-up.

In management of teaching and learning, it is also recommended to increase (rather than reduce) the number of face-to-face sessions for maths knowledge sharing (or teaching), though unfortunately it has become a policy trend in the HEIs to decrease the number of sessions. It is also worthwhile to remind the practitioners that while maths learning software technology such as MyMathLab is a teaching tool, it is less effective in sharing tacit knowledge of maths.

There are different types of pedagogies in the educational domain, but they promote methods of teaching that are mainly based on students' style of learning (such as blended learning, use of technology, etc.) and are less facilitative in collaborative practices and interactions. Recently though, students' peer-assisted approaches have been practised. Yet, it is important to have a peer in the team who knows the subject extremely well and who patiently guides the process of learning through practising, because learning/practising maths is time consuming and also needs facilitation. Here is where this research offers a way to apply '*guided self-organisation'* based on the structure of the skills-mix and facilitate learning/knowledge sharing. The guided self-organisation in teams is particularly important when there is fragmentation in students' network (revealed by SNA), which represents a barrier to effective management of social capital. In this research, such fragmentation was based on streaming strategy and timetabling at management level. Hence, the skills-mix ratio of 1:4 for highly-skilled to low-skilled students in teams was calculated and suggested (see Section 4.2.2.12 and Section 4.3.2.1.2).

Another contribution to practice in this research relates to providing a method of collaborative experiential learning based on domains of viable knowledge that is truly bottom-up and learner-centred. It also reduces the power distance between learners and lecturers/tutors. In addition, it works effectively for skills development and performance improvement and is easy for practitioners to understand (see method note in Appendix 2). Chapter 4 of this thesis represents the application of systemic action/operational research in two cycles. Therefore, it is recommended to consider the approach in this research as one way of moving away from teacher-centred solutions.

6.4 Limitations and Implications for Further Research

Despite academic contribution to knowledge and practice, any research is bound by limitations. It is important to recognise the limitations and to suggest areas for further studies. This research is no exception.

First, the time limit of UK doctoral research degrees (which is four years) limits the full establishment of action research methods as well as longitudinal and cyclical studies. This timeframe also limits the researcher's capacity to test the effectiveness of the ideas, methods and approaches in other contexts, in order to make a strong claim on the transferability of the research. Hence, the researcher could only claim that the SCOR multi-methodology of this research has 'potential for transferability'.

Second, the case study university (the BSUKU) of this research was under a major change to centralise the management operation processes e.g. timetabling. HR, finance, etc. Among all, timetabling was the process that disrupted operational plan 2 of this research. Hence, the designed skills-mix could not be actually scheduled in the tutorial sessions. If this could have happened then all students could have benefitted from the present action research. Nonetheless, the researcher managed to implement a solution by voluntarily offering extra maths sessions, as in operational plan 3. Although the number of participants became limited to 101 students (collectively in both cycles), it created an opportunity to compare the final performance of those who participated in the systemic solution and those who did not. Further research could focus on implementing the systemic solution in the tutorials of the full cohort of first-year students and on having a higher number of participants. This would lead to a larger amount of data and might provide a better understanding of the processes and complexities involved in managing learners' maths knowledge network, though it is operationally much more difficult.

Third, in the implementation of operational plan 3 (maths knowledge network), students learned the basics concepts of VSM and discussed the method of application of VSM in the maths knowledge network. However, since maths contents are by nature difficult to learn, the researcher was cautious and reasoned not to increase the level of difficulty by introducing expert VSM concepts, because learners were first-year undergraduate students and mainly had no previous work experience which could be used to fully relate to and follow the complex concepts. Nonetheless, better insights and understanding are required on how expert VSM might affect a team's knowledge brokering, and how it influences the leading patterns of knowledge sharing in the maths knowledge network. However, educational providers might resist following this.

Fourth, incorporating the use of maths learning software such as MyMathLab was not in the scope of this research. However, in terms of organising technology for learning, it would be interesting to investigate whether Johnson and Liber's (2008) PLE approach can effectively support the maths learning. Similar to VSM implementation in the SCOR multi-methodology of this research, Johnson and Liber's (2008) PLE approach permits the learners to take control of their own learning. They use VSM and assert that physical engagement with the learning technological instruments plays a key role in empowering the learners to organise their own technological learning sphere. If Johnson and Liber's (2008) PLE approach could effectively handle the complexities involved in learning maths, then the SCOR multi-methodology can be developed further to also include use of technological software tools in maths learning as well as in management of maths learning. In fact, the two approaches can be complementary, because capturing change in skills development through the use of technology would be much easier. This can be achieved for example through allowing the learners to use technological learning instruments, evaluating their own skills at the beginning and end of each session. Hence, the highly-skilled learners would not be too stressed by administrative tasks. However, this complementary idea needs empirical evidence to show its effectiveness in maths skills development and performance improvement.

Fifth, and as discussed in Section 2.3.2.1.2 and Section 4.2.1.2.2, a system for management of teaching is different from a system for management of learning, since learning is emergent and developmental. As part of management of learning, there is the potential to intentionally create the conditions for the emergence of a new level of recursion (e.g. through allocating resources, offering extra time, etc.). This research provides some evidence that might possibly signal the emergence of such recursion in the learner's knowledge network. For instance: 1) there were physical spaces allocated for learners to perform their activities (e.g. the rooms booked in the university); 2) the module leader announced the scheduling of extra maths sessions on the E-bridge for all. The lecturers also suggested that the learners attend the extra maths sessions. This was a recognition of the learners' collective efforts in their knowledge network; 3) the learners learned how to perform their duties; 4) intangible outcomes such as skills and capabilities were developed in the extra maths sessions over time. This gradually improved the students' performance in terms of success in the final exam. It would be interesting to further study other mechanisms and conditions, along with those presented in this research, and how long would be needed for the new recursion level to stem out or strengthen its own capabilities and to become fully developed, recognised and institutionalised in the system for management of learning.

Another area for further research pertains to the idea of considering the university learners as co-creators, co-producers or collaborators of knowledge as opposed to costumers. Although these theories have been back-dropped in reality (Bovill et al., 2015), it is important to investigate how said concepts can be better introduced again in order to shape the ways of knowledge sharing and management of learning. In particular, since those back-dropped theories are not soft-OR-orientated, combining soft-OR tools and methods in such approaches can be facilitative in the management of learning.

Further, since this research provided empirical evidence regarding the application of VSM+SNA for collective knowledge sharing as an effective approach for leadership development in the educational context, further research is needed in other contexts, e.g. in business organisations, in healthcare, in engineering, and in the military environment.

Finally, this research attempted to provide evidence to counter the argument of Ulrich (1981) and Jackson (2003) regarding VSM being merely a functionalist-mechanistic approach that does not deal with social aspects and motivation. In this research, all of the students who participated in the maths knowledge network and set/aligned their goals were highly motivated to attend their exam in order to achieve the outcomes of their efforts. They all did so in both cycles. In contrast, of those who did not participate, 14% in the first cycle and 9% in the second cycle were not motivated to attend the exam, and they were revealed by a mark of no-show. It is important that other interested researchers lead this line of evidence further. Empirical justifications for or against this claim are sought greatly. In particular, it is suggested to sufficiently focus on the first two domains of viable knowledge in Achterbergh and Vriens (2002).

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Appendix 0: The Main Systems Thinking Theories

First Wave of Systems Thinking Theories – HARD Systems theories

Development	Concepts	Developing author(s)
General Systems Theory	This theory is developed based on the behaviour of biological organisms. It relates to the laws, principles and models that exist and can be applied on any other kind of systems.	Von Bertalanfy (1956)
Systems Engineering	It is the multidisciplinary science of design and management of complex systems which focuses on efficiency in operational processes and optimisation.	Hall (1962), Jenkins (1972)
Systems Dynamics (Quantitative)	It is a modelling approach to figure out what a complex system is in terms of its dynamic behaviour through recognition of many interrelationships among its components over time considering also those connections that are time-delayed.	Forrester (1961; 1969), Meadows et al. (1972), Senge, (1990), Maani & Cavana (2000)
Systems Analysis	It focuses on the methods and the knowledge of modern science to restructure the problems and assists those actions that are related to policy, using systemic assessment of various solutions and provide evidence and possible outcomes for cost, risks and effectiveness.	Optner (1965) Miser & Quade (1985)
Hard Operations Research	It relates to methodologies that consider explicit as well as implicit suppositions about the systems which you want to understand and transform. It is supported through scientific research.	Churchman et al. (1957)
First Order Cybernetics	First Order Cybernetics focuses particularly on more output-directed and functional systems that have a type of command and control.	Ashby (1940, 1945), Wiener (1948), McCulloch & Pitt (1943) Walter (1953a, b) Von Neumann (1961)
Socio-Technical Systems	It is an approach to recognise the interaction between people and the technology in organisations.	Trist & Bamforth (1951)

Second Wave of Systems Thinking Theories – SOFT Systems Theories

Development	Concepts	Developing author(s)
Soft Systems Methodology	It is a seven steps methodology model derived from a four steps initial model. It encourages practitioners not to use it as prescription but rather as a heuristic instrument for inquiry to study the complexities of problems in real world.	Checkland (1972, 1981, 1999), Checkland and Scholes (1990)
Strategic Assumption Surfacing and Testing	It deeply explores people's beliefs and assumptions via dialectical discussions. It brings together those who design the alternative proposals and those influenced by. It then tests and assesses the alternative strategic proposals.	Mitroff & Emshoff (1979) Mitroff & Mason (1981)
Interactive Planning	It relates to long-term thinking and includes a participatory process, encouraging stakeholders to involve in two scenarios of 'idealisation' and 'realisation'. Ideal future designs should be feasible, viable and adaptable. This approach liberates participants from being constrained by current assumptions and exploits the creativity.	Ackoff (1981, 2001)
System Dynamic (Qualitative)	This is a shift from quantitative system dynamic in first wave to a qualitative and subjective approach in second wave. It uses models to assist stakeholders' learning in a participatory method.	Senge, (1990), Morecroft & Sterman (1994)
Second Order Cybernetics	It is a constructive theory based on which (a) knowledge is outcome of social agents' active cognitive constructions, (b) it does not aim to represent the external reality but to create and maintain the organism's equilibrium, (c) the value of knowledge can merely be tested through its viability in experiencing the world and not by comparison with independent realties.	Bateson & Mead (1973), von Foerster (1995)
Strategic Options Development and Analysis	Cognitive mapping is used as a soft-OR modelling technique in a process-oriented approach in order to capture interrelated causal maps and to structure and model the messy problems. This method is useful for developing strategic options and their analysis.	Eden (1989)

Third Wave of Systems Thinking Theories – Critical Systems Theories

Development	Concepts	Developing author(s)
Critical Systems Heuristics	It relates to the process of critical review on decisions made on boundaries (judgements) in order for practical suggestions. It therefore strives to provide a theoretical framework to identify, discus and debate the boundary judgments with hands-on emancipation.	Ulrich (1983)
Systems of Systems Methodologies	This is a matrix framework to select the right approach for the given circumstances. It is based on system being simple or complex and the participants being unitary, pluralist or coercive.	Jackson and Key (1984) Jackson (2003)
Liberating Systems Theory	It is a sociological perspective to include methodology, ontology, epistemology and ideology in order to address suppressions and to make road for emancipations and liberations.	Flood (1990)
Interpretive Systemology	This is a theoretical foundation for interpretive systems developed from phenomenology. It proposes that phenomena (in broad sense) and institutions (in particular) may be considered distinctions made on a background. It claims universality in all systems thinking approaches. However, this claim refuted by Minger (1992).	Fuenmayor (1991)
Total Systems Intervention	This is a meta-methodology to assist in selecting other systems methodologies through creativity, choices and implementation.	Flood and Jackson (1991)
Systemic Intervention	It suggests that with due attention to be paid for a pluralist cluster of methods, a boundary critique is required to examine the circumstances prior to selecting or designing an approach in order to arrive at the intended intervention.	Midgley (2000)

Appendix 1: Different Paradigm and Philosophies (Mukhuty, 2013; p.154)

Criteria	Positivism	Post positivism	Interpretivism	Critical theory	Constructivism	Feminism	Post Modernism	Pragmatism
Research aim	Discovering natural laws and explanation to enable prediction and control		Understand and describe meaningful social action	Critique, Smash myths and enable transformation through empowerment; emancipation and restitution	Comprehension and reconstruction	Smash myths and empower people to advance values of nurturing others and equality	Express the subjective self	Action and Change
Nature of Social Reality	Stable pre-existing patterns or order that can be discovered		Fluid definitions of a situation created by human interaction	Conflict filled and governed by hidden underlying structures		Conflict-Filled structured power relations that keep many people oppressed	Chaotic and fluid without any real patterns or master plan	Symbolic realism
Nature of Human beings	Self-interested and rational individuals who are shaped by external forces		Social beings who create meaning and who constantly make sense of their worlds	Creative, adaptive people with unrealized potential, trapped by illusion and exploitation		Creative, gendered beings with unrealized potential who are often trapped by unseen forces	Creative, dynamic beings with unrealized potential	Engaged in Change and Development
Nature of Knowledge	Verified hypothesis established as facts or laws	Non-falsified hypotheses that are probable facts or laws		Structural and historical insights	Individual reconstructions' coalescing around consensus			Constructive knowledge
Knowledge Accumulation	Accretion -"building blocks" adding to the "edifice of knowledge"; generalizations and cause-effect linkages		Historical revisionism; generalization by similarity	More informed and sophisticated reconstructions; vicarious experience				Pre-assessment, intervening & Continual development, monitoring, Post-assessment
Theory looks like	A logical deductive system of interconnected definitions, axioms and laws		A description of how a group's meaning system is generated and sustained	A critique that reveals true conditions and helps people see the way to a better world		A critique that reveals true conditions and helps people see the way to a better world	A performance or work of artistic expression that can amuse, shock, or stimulate others	Useful for action
An explanation that is true	Logically connected to laws and based on facts		Resonates or feels right to those who are being studied	Supplies people with tools needed to change the world		Supplies ideas/tools to help liberate people from oppressive relations	No one explanation is more true; all are true for those who accept them	Assessment and intervention
Place for Values	Influence or inclusion of values is kept to minimal except when choosing a topic for research		Values are an integral part of social life: no group's values are wrong, only different	All science must begin with a value position; some positions are right, some are wrong	Values and value influences are included and considered ineluctable in shaping inquiry outcomes	Values are essential to research, and feminist ones are clearly preferred	Values are integral to research, but all value positions are equal	Values are not predetermined and thus, cannot be eternal

Appendix 2: Method Note – 31 domains of viable knowledge

Collaborative knowledge sharing and experiential learning

Class goal: To create maths knowledge network for developing maths skills and getting passed in the exam.

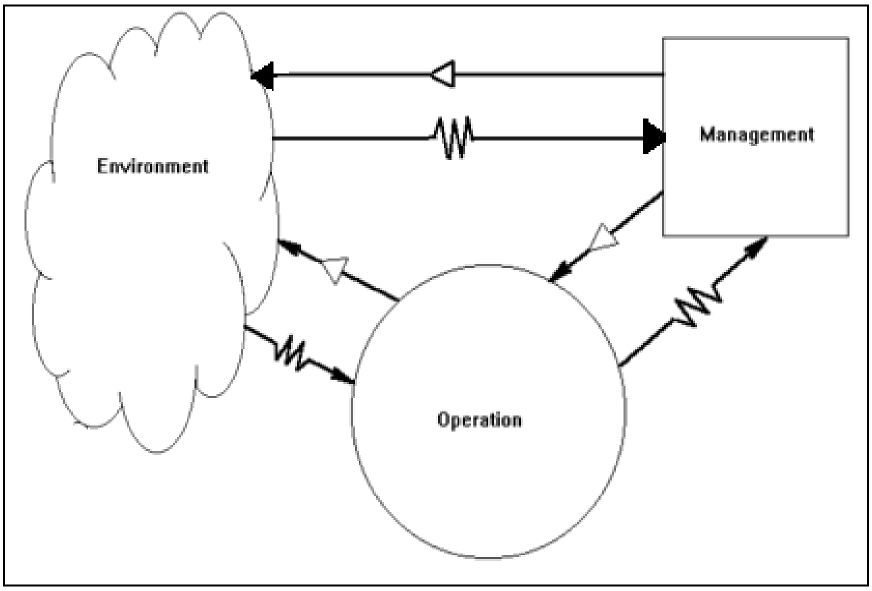
Teams' goal: To answer to all questions by helping each other in the teams.

Method: You will be in teams of 5. One of you knows maths well. I will facilitate the assembly of your team with a ratio of 1:4. A set of questions is given to you to solve together in a friendly manner in your team. Look at the questions first and see if you feel confident to solve them. Attempt to solve the questions each by yourself first and check your answers with other team members. The highly skilled peer will also check how you have answered the questions. I will do too sometimes. If you observe any difference, you can report your struggles and ask peers in your team to discuss how they have answered correctly. If no one in your team knew how to deal with the question, ask me. Either I will help you with answering the question myself or I will ask someone from another team who have solved the question to come and help. You can also directly ask other teams to see if anyone has had a success. So, you get the guide you needed within the session. If no one in the class knows how to solve the question, I will facilitate step-by-step on solving the question with all of you on the board. Attempt the next question. You have been given similar questions on each topic. After learning how to solve the first question, now practice solving second and third questions on the same topic. Ask for help if you are stuck again. Self-organise a discussion in your team about what was your mistake and the causes of your mistake and how you corrected it. I will also guide you. Listen carefully to the problem solving experience of other teammates too. Sometimes you will see they are using easier and more understandable methods. So, your knowledge about the current topic will be updated. The highly skilled student will ensure all in your team have understood the tasks and guide you with self-assessment on the process. Remember, your main activity in the team is to learn by practice and reflection. I will consult the team members about how they experienced with practice questions on the way to developing their skill. Any team that successfully solves a maths question and practice exercises of that type, has reached a higher level of expertise. Therefore, its team members are counted as skilled persons on that particular question and can help other teams. Then, check against your team goal. Have you reached the team goal? If so, make a bigger goal in your team next time. If not, what questions you struggled? How many left unanswered? what was the cause of it and what will you do to reach your goal next time? What strategies are more suitable? Brainstorm in your team for this and choose a strategy and a method to get there. Ask the highly skilled student in your team to give some advice to the team too. Your highly skilled member of the team might suggest revising the team goal. S/He will check/compare the current goal and the desired team goal. What other things, resources, conditions, etc. you may need for improving your knowledge sharing in the team? Discuss together and write the main point on your feedback sheets. Your highly skilled members will consult you to fill the team feedback forms. I will collect them and discuss collectively in the class on our progress. We will review the ideas and innovate through with a practical method as a way forward for improvement.

We will all maintain the ground rules and university's code of conduct. Conflicts will be peacefully resolved by the support of module leader upon report from anyone.

Wish you all success.
Good Luck

Appendix 3: Basics of Viable System model



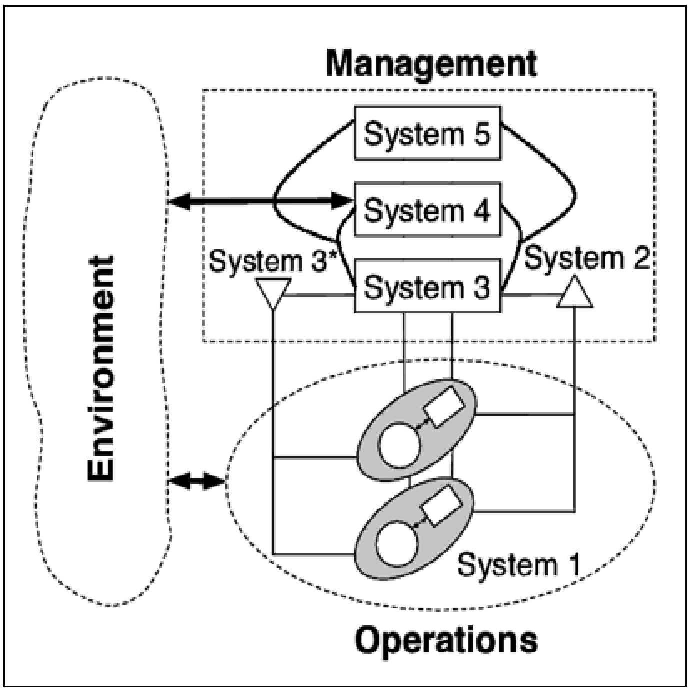
Operation: You are Studying and Learning in the Business School.

Management: Module Leaders and other management functions in the Busines School teach, regulate, assess, manage and strategize for your studies and you learning. You give feedback to module leaders and they consider it.

Environment: You keep checking on what opportunities are available in extern environment for you to take for the success in your studies and what threat come from there that may distract you from your success. Module leaders ar management functions in the Business School also are scanning the extern environment to bring in the new methods, new technologies, etc. relevant to you success, or they may make decisions on eliminating things that might cause yo failure.

The relationship and feedback loops among these three components makes it system. This is the basics of a management model that is called **Viable Syste Model**.

Question: Can you now envisage yourself or a team of you to think like a modu leader and management functions of the Business School for your own success?



System 1 is all about main activities to perform for the success.
System 2 is more about tactical planning, conflict resolution and coordination.
System 3 is more about regulating and assessing the process in system one.
System 3* is more about auditing the procedures and optimising the work system one.
System 4 is more about strategizing, decision-making and intelligence.
System 5 is more about governance and identity of the whole system.
Again, there are connections among the five systems above, and with th environment.

Question: Can you now envisage your teams and the class to perform the operati and management functions (System 1 to 5) for your collective success?

Appendix 4: Motivational note

Motivation for students:

You know that learning Maths is different from other subjects. It consists of learning both the concepts and process of applying these concepts in any given Maths question. Therefore, it is very abstract and requires new ways of learning.

You may join this maths knowledge network (maths extra sessions) to help each other in understanding and solving difficult maths questions. You will practice together and become skilful in any topic relevant to your APS-Maths.

This approach is going to contribute to your individual performance through collective knowledge sharing and collaborative experiential learning.

- If you are already a highly skilled student, joining this session will help you reducing the chance of making simple mistakes in the exam through getting experience of checking your peers' work.
- If you are not highly skilled yet, then you will have a chance to discuss your mistakes and get your work checked by highly skilled students or by the researcher. You can also check other peers' work and ask questions to get more insights.
- You will all make new friends here, which is a great thing.

It is expected that you will become more confident, reach a higher maths skill level and get better results, after a series of Math's knowledge sharing sessions. Performing according to the plan, you will also gain specific skills and experience such as time management, problem solving, teamwork ... You can add them on your CV.

Thank you for joining this *APS-Maths* intervention and Good Luck. ☺

Appendix 5: Team feedback form

TEAMS FEEDBACK FORM – MATHS KNOWLEDGE NETWORK		
Date:		
Time:		
Team members' names:		
1	What went well and what did not go so well in meeting your team's expected performance?	
2	What was the reason that you could not meet your team's expected performance?	
3	What will you do next time to meet the team's performance expectation?	
4	How would you implement your plan to meet the team's expected performance next time?	
5	What specific things do you need to tackle the problems and manage your teamwork for better knowledge sharing?	
6	How happy you are with the guide and support you got from your teammates in problem solving? Rate from 1 to 10 (1 is weak and 10 is strong)	
7	How happy you are with the guide and support you received from your tutor in problem solving? Rate from 1 to 10 (1 is weak and 10 is strong)	

Appendix 6: Individual's Feedback form

MEMBER'S FEEDBACK FROM– MATHS KNOWLEDGE NETWORK		
Date:		
Time:		
Your name:		
1	At the beginning of this session today, how confident you feel you are in your skills of maths? Rate from 1 to 10 (1 is weak and 10 is strong)	
2	At the beginning of this session today, how competent you feel you are in using your skills of maths? Rate from 1 to 10 (1 is weak and 10 is strong)	
3	Who are in your team?	
4	Who was/were the most helpful individual/s in your team?	
5	What can be done to help you better share your problems in the team?	
6	What conditions, equipment, resources, etc. can help your teammates to better share their knowledge with you if provided?	
7	At the end of this session today, how confident you feel you are in your skills of maths? Rate from 1 to 10 (1 is weak and 10 is strong)	
8	At the end of this session today, how competent you feel you are in using your skills of maths? Rate from 1 to 10 (1 is weak and 10 is strong)	
9	At the end of this session today, how satisfied are you with your progress? Rate from 1 to 10 (1 is weak and 10 is strong)	

Appendix 7: Schedule of OP 3 sessions – 1st cycle

Date	Time	Duration	Location
19/02/2016	16:15 – 18:15	2 hour	Library Teaching room 3
23/02/2016	16:15 – 18:15	2 hour	Library Teaching Room 3
26/02/2016	16:15 – 18:15	2 hour	Library Teaching Room 2
08/03/2016	16:15 – 18:15	2 hour	Library Teaching Room 3
05/04/2016	16:15 – 18:15	2 hour	Library Teaching Room 2
12/04/2016	16:15 – 18:15	2 hour	Library Teaching Room 3
19/04/2016	16:15 – 18:15	2 hour	Library Teaching Room 2
21/04/2016	16:15 – 18:15	2 hour	Library Teaching Room 4
25/04/2016	16:15 – 18:15	2 hour	Library Teaching Room 6
26/04/2016	16:15 – 18:15	2 hour	Library Teaching Room 3
28/04/2016	16:15 – 18:15	2 hour	Library Teaching Room 2
03/05/2016	16:15 – 18:15	2 hour	Library Teaching Room 4
05/05/2016	16:15 – 18:15	2 hour	Library Teaching Room 6
09/05/2016	16:15 – 18:15	2 hour	Library Teaching Room 1
10/05/2016	16:15 – 18:15	2 hour	Library Teaching Room 2
11/05/2016	16:15 – 18:15	2 hour	Library Teaching Room 2
13/05/2016	16:15 – 18:15	2 hour	Library Teaching Room 6
15/05/2016	10:00 – 18:00	8 hour – Day Long	Library Teaching Room 3
16/05/2016	16:15 – 18:15	2 hour	Library Teaching Room 4

Appendix 8: Schedule of OP 3 sessions – 2nd cycle

Date	Time	Duration	Location
24/11/2016	18:15 - 20:15	2 hours	Library Teaching room 2
15/02/2017	18:15 - 20:15	2 hour	Library Teaching room 4
20/02/2017	18:15 - 20:15	2 hour	Library Teaching Room 4
21/02/2017	18:15 - 20:15	2 hour	Library Teaching Room 2
24/02/2017	18:15 - 20:15	2 hour	Library Teaching Room 4
01/03/2017	18:15 - 20:15	2 hour	Library Teaching Room 3
05/03/2017	12:00 – 14:00	2 hour	Library Teaching Room 3
14/03/2017	12:00 – 14:00	2 hour	RBB 312
15/03/2017	18:15 - 20:15	2 hour	Library Teaching Room 2
31/03/2017	18:15 - 20:15	2 hour	Library Teaching Room 3
12/04/2017	10:00 - 12:00	2 hour	Library Top Floor
20/04/2017	18:00 – 20:00	2 hours	Library Teaching Room 2
23/04/2017	18:15 - 20:15	2 hour	Library Teaching Room 4
27/04/2017	18:00 – 20:00	2 hour	Library Top Floor
28/04/2017	18:15 - 20:15	2 hour	Library Teaching Room 3
05/05/2016	18:15 - 20:15	2 hour	Library Teaching Room 4
07/05/2016	18:15 - 20:15	2 hour	Library Teaching Room 4
11/05/2016	18:15 - 20:15	2 hour	Library Teaching Room 4

Appendix 9: Ethical Approval

UNIVERSITY OF Hull

Hull University Business School
Research Office
T +44(0)1482 463536
E h.carpenter@hull.ac.uk

Miss Salimeh Pour Mohammad
2 Cromer Street
HULL
HU5 1BG

Ref: HUBSREC 2015/45

11 February 2016

Dear Salimeh

Re: A viable system perspective to knowledge sharing and network analysis

Thank you for your research ethics application.

I am pleased to inform you that on behalf of the Business School Research Ethics Committee at the University of Hull, Dr Ashish Dwivedi has approved your application on 11 February 2016.

I wish you every success with your research.

Yours sincerely,

Hilary Carpenter
Secretary,
Research Ethics Committee

Accredited by Association of MBAs

Hull University Business School
University of Hull
Hull, HU6 7RX
United Kingdom
School reception
+44 (0) 1482 347500
www.hull.ac.uk/hubs

Appendix 10: Consent Form

Consent Form

UNIVERSITY OF Hull

Business School

RESEARCH ETHICS COMMITTEE

CONSENT FORM: SURVEYS, QUESTIONNAIRES

I, of

Hereby agree to participate in this study to be undertaken

By: PhD student – Salimeh Pour Mohammad

and I understand that the purpose of the research is *to investigate on* a Viable System Perspective to Knowledge Sharing and Network Analysis through which is equivalent to a peer assisted learning and practice.

I understand that

1. Upon receipt, my questionnaire and interview data will be coded and my name and address kept separately from it.
2. Any information that I provide will not be made public in any form that could reveal my identity to an outside party i.e. that I will remain fully anonymous.
3. Aggregated results will be used for research purposes and may be reported in scientific and academic journals (including online publications).
4. Individual results **will not** be released to any person except at my request and on my authorisation.
5. That I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and any information obtained from me will not be used.

Signature: Date:

The contact details of the researcher are: S.Pour-Mohammad@2013.hull.ac.uk

The contact details of the Supervisors are: R.Vidgen@hull.ac.uk and A.Espinosa@hull.ac.uk

In some cases, consent will need to be witnessed e.g. where the subject is blind/ intellectually disabled. A witness must be independent of the project and may only sign a certification to the level of his/her involvement. A suggested format for witness certification is included with the sample consent forms. The form should also record the witnesses' signature, printed name and occupation. For particularly sensitive or exceptional research, further information can be obtained from the HUBS Research Ethics Committee Secretary, e.g., absence of parental consent, use of pseudonyms, etc)

NOTE:
In the event of a minor's consent, or person under legal liability, please complete the Research Ethics Committee's "Form of Consent on Behalf of a Minor or Dependent Person".

Business School

Appendix 11: Generic Information for the Participants

Hull University Business School
The University of Hull
Hull HU6 7RX
United Kingdom

Date:

Dear……………………………,

This letter is an invitation to consider participating in a study we are conducting at Hull University Business School. We would like to provide you with more information about this project and what your involvement would entail if you decide to take part.

The aim of the project is to investigate how knowledge of maths is being shared optimally in a class of students, over a period of second semester for the year 2015-16. The project focuses on knowledge sharing based on peer assisted learning and practice. We believe that because you are actively involved in the learning and practicing maths, you are best suited to be referred for the various issues related to such knowledge sharing.

Participation in this study is voluntary. It will involve your dynamic maths learning and practice process (as an action research for us), an interview of approximately half an hour in length to take place in a mutually agreed upon location in the university campus, as well as feedback forms. You may decline to answer any of the interview questions, if you so wish. Furthermore, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher(s). With your permission, the interview will be audio recorded to facilitate collection of information, and later transcribed for analysis. All information you provide is considered strictly confidential. Your name and any name you mention will be coded prior to analysis and will not appear in any thesis or report resulting from this study, however, with your permission anonymous quotations may be used. Data collected during this study will be retained for 1 year in a locked office at the University of Hull. Only researchers associated with this project will have access. There are no known or anticipated risks to you as a participant in this study. If you have any question at any stage of this research please send an email to S.Pour-Mohammad@2013.hull.ac.uk

Should you have any concerns about the conduct of this research project, please contact the Secretary, HUBS Research Ethics Committee, University of Hull, Cottingham Road, Hull, HU6 7RX; Tel No (+44) (0)1482 463536.

We hope that the results of our study will be of benefit to the organisations directly involved in the study, other voluntary recreation organizations not directly involved in the study, as well as to the broader research community.

We very much look forward to speaking with you and thank you in advance for your assistance in this project.

Yours Sincerely,

Researcher: PhD student - Salimeh Pour Mohamad
Thesis Supervisors: Prof. Richard Vidgen and Dr. Angela Espinosa

Appendix 12: Interview Questions

1. What is the purpose of APS module in your views? Why APS Module is a strategic one?
2. What different roles you had for managing APS Module?
3. In your capacity what processes you undertook in the management of APS module? If there was an issue how you handle the case, any example?
4. Who else is involved in the management of this typical module?
5. Do you know what is going well and what does not go so well with regards to managing APS Module?
6. How is direct communication between you and the students?
7. In your view, what could be the reasons for achieving/not achieving the expected performance in APS?
8. In your views what recourses and conditions the management team needs to achieve the expected performance?
9. Have those involved in managing the APS, the autonomy to perform effectively?
10. How is the mechanism to provide synergy among module management team or among students?
11. Are there mechanism to deal with conflicting interests in the module management team?
12. Is there any enabling mechanism for sustainable governance for this specific module?
13. How critical issues to viability are dealt with?
14. What could be done for YOU to do better in your role, if any?

Appendix 13: Paired two sample t-test for means – Involved in knowledge Network, 1st Cycle

Mark Band	t-Test: Paired Two Sample for Means	Formative test result	Final Exam Results
70+	Mean	78.9375	88.75
	Variance	22.17410714	65.35714286
	Observations	8	8
	Pearson Correlation	0.864505396	
	Hypothesized Mean Difference	0	
	df	7	
	t Stat	-5.956573947	
	P(T<=t) one-tail	0.00028316	
	t Critical one-tail	1.894578605	
	P(T<=t) two-tail	0.000566321	
	t Critical two-tail	2.364624252	
	Effect size	2.1	
60 - 69	Mean	63.16666667	74.16666667
	Variance	6.266666667	141.3666667
	Observations	6	6
	Pearson Correlation	0.805222366	
	Hypothesized Mean Difference	0	
	df	5	
	t Stat	-2.698489492	
	P(T<=t) one-tail	0.021430681	
	t Critical one-tail	2.015048373	
	P(T<=t) two-tail	0.042861362	
	t Critical two-tail	2.570581836	
	Effect size	1.1	
50 - 59	Mean	54.7	61.6
	Variance	10.95	4.3
	Observations	5	5
	Pearson Correlation	0.469989799	
	Hypothesized Mean Difference	0	
	df	4	
	t Stat	-5.201070694	
	P(T<=t) one-tail	0.003255681	
	t Critical one-tail	2.131846786	
	P(T<=t) two-tail	0.006511361	
	t Critical two-tail	2.776445105	
	Effect size	2.3	

< 50	t-Test: Paired Two Sample for Means		
		Formative test result	*Final Exam Results*
	Mean	38.25	47.8
	Variance	195.625	124.4
	Observations	10	10
	Pearson Correlation	0.930560335	
	Hypothesized Mean Difference	0	
	df	9	
	t Stat	-5.542249635	
	P(T<=t) one-tail	0.000180002	
	t Critical one-tail	1.833112933	
	P(T<=t) two-tail	0.000360004	
	t Critical two-tail	2.262157163	
	Effect Size	1.7	

Appendix 14: Paired two sample t-test for means – Not-involved in knowledge Network, 1st Cycle

Mark Band			
70+	t-Test: Paired Two Sample for Means		
		Formative test result	*Final Exam Results*
	Mean	77.74107143	86.8035714
	Variance	28.8726461	144.087987
	Observations	56	56
	Pearson Correlation	0.660793647	
	Hypothesized Mean Difference	0	
	df	55	
	t Stat	-7.240954457	
	P(T<=t) one-tail	7.59838E-10	
	t Critical one-tail	1.673033965	
	P(T<=t) two-tail	1.51968E-09	
	t Critical two-tail	2.004044783	
	Effect Size	0.96	
60 - 69	t-Test: Paired Two Sample for Means		
		Formative test result	*Final Exam Results*
	Mean	64.1	70.2
	Variance	6.963157895	27.01052632
	Observations	20	20
	Pearson Correlation	0.077138788	
	Hypothesized Mean Difference	0	
	df	19	
	t Stat	-4.833217022	
	P(T<=t) one-tail	5.7755E-05	
	t Critical one-tail	1.729132812	
	P(T<=t) two-tail	0.00011551	
	t Critical two-tail	2.093024054	
	Effect Size	1.06	
50 - 59	t-Test: Paired Two Sample for Means		
		Formative test result	*Final Exam Results*
	Mean	53.26666667	57.13333333
	Variance	12.38809524	53.40952381
	Observations	15	15
	Pearson Correlation	0.459484496	
	Hypothesized Mean Difference	0	
	df	14	
	t Stat	-2.306399396	
	P(T<=t) one-tail	0.018449825	
	t Critical one-tail	1.761310136	
	P(T<=t) two-tail	0.03689965	
	t Critical two-tail	2.144786688	
	Effect Size	0.59	

< 50	t-Test: Paired Two Sample for Means		
		Formative test result	*Final Exam Results*
	Mean	33.89285714	38.42857143
	Variance	103.4211672	121.8118467
	Observations	42	42
	Pearson Correlation	0.844969023	
	Hypothesized Mean Difference	0	
	df	41	
	t Stat	-4.929793392	
	P(T<=t) one-tail	7.02723E-06	
	t Critical one-tail	1.682878002	
	P(T<=t) two-tail	1.40545E-05	
	t Critical two-tail	2.01954097	
	Effect Size	0.75	

Appendix 15: Paired two sample t-test for means –Involved in knowledge Network, 2nd Cycle

Mark Band			
60 - 69	t-Test: Paired Two Sample for Means		
		Formative Test	Final exam result
	Mean	63.54545455	72.2727273
	Variance	4.672727273	14.3181818
	Observations	11	11
	Pearson Correlation	0.786885276	
	Hypothesized Mean Difference	0	
	df	10	
	t Stat	-11.70209719	
	P(T<=t) one-tail	1.8496E-07	
	t Critical one-tail	1.812461123	
	P(T<=t) two-tail	3.69921E-07	
	t Critical two-tail	2.228138852	
	Effect size	3.3	
50 - 59	t-Test: Paired Two Sample for Means		
		Formative Test	Final exam result
	Mean	53.96	63.38
	Variance	6.04	10.19333333
	Observations	25	25
	Pearson Correlation	0.26752868	
	Hypothesized Mean Difference	0	
	df	24	
	t Stat	-13.576814	
	P(T<=t) one-tail	4.6583E-13	
	t Critical one-tail	1.71088208	
	P(T<=t) two-tail	9.3166E-13	
	t Critical two-tail	2.06389856	
	Effect Size	2.72	
< 50	t-Test: Paired Two Sample for Means		
		Formative Test	Final exam result
	Mean	35.46153846	51.96153846
	Variance	252.2692308	160.0608974
	Observations	13	13
	Pearson Correlation	0.913286031	
	Hypothesized Mean Difference	0	
	df	12	
	t Stat	-8.83988203	
	P(T<=t) one-tail	6.67001E-07	
	t Critical one-tail	1.782287556	
	P(T<=t) two-tail	1.334E-06	
	t Critical two-tail	2.17881283	
	Effect size	2.2	

Appendix 16: Paired two sample t-test for means – Not Involved in knowledge Network, 2nd Cycle

Mark Band			
70 +	t-Test: Paired Two Sample for Means		
		Formative Test	Final exam results
	Mean	72.58333333	75.5
	Variance	10.99242424	24.36363636
	Observations	12	12
	Pearson Correlation	0.52773163	
	Hypothesized Mean Difference	0	
	df	11	
	t Stat	-2.375954817	
	P(T<=t) one-tail	0.018381504	
	t Critical one-tail	1.795884819	
	P(T<=t) two-tail	0.036763008	
	t Critical two-tail	2.20098516	
	Effect Size	0.68	
60 - 69	t-Test: Paired Two Sample for Means		
		Formative Test	Final exam results
	Mean	63.33333333	68.19791667
	Variance	9.971631206	16.63552748
	Observations	48	48
	Pearson Correlation	0.682812056	
	Hypothesized Mean Difference	0	
	df	47	
	t Stat	-11.22274156	
	P(T<=t) one-tail	3.39886E-15	
	t Critical one-tail	1.677926722	
	P(T<=t) two-tail	6.79773E-15	
	t Critical two-tail	2.011740514	
		Effect size	1.6
50 - 59	t-Test: Paired Two Sample for Means		
		Formative Test	Final exam results
	Mean	54.93203883	61.66019417
	Variance	7.240434038	11.99614506
	Observations	103	103
	Pearson Correlation	0.569234679	
	Hypothesized Mean Difference	0	
	df	102	
	t Stat	-23.24882051	
	P(T<=t) one-tail	7.398E-43	
	t Critical one-tail	1.659929976	
	P(T<=t) two-tail	1.4796E-42	
	t Critical two-tail	1.983495259	
	Effect Size	2.33	

< 50	t-Test: Paired Two Sample for Means		
		Formative Test	*Final exam results*
	Mean	34.3263158	45.27368421
	Variance	107.966853	209.9296193
	Observations	95	95
	Pearson Correlation	0.81498906	
	Hypothesized Mean Difference	0	
	df	94	
	t Stat	-12.531267	
	P(T<=t) one-tail	4.5928E-22	
	t Critical one-tail	1.66122586	
	P(T<=t) two-tail	9.1857E-22	
	t Critical two-tail	1.98552344	
	Effect size	1.26	