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Systemic Intervention for Computer Supported Collaborative Learning

Abstract

This paper presents a systemic intervention approach as a means to overcome the methodological challenges involved in research into Computer-Supported Collaborative Learning applied to the promotion of Mathematical Problem-Solving skills (CSCL-MPS). These challenges include the development of an integrated analysis to study several aspects of the learning process; and the need to reflect on learning purposes, the context of application and participants' identities. The focus of systemic intervention is on how to consider whose views and what issues and values should be considered pertinent in an analysis. Systemic intervention also advocates the use of different methods from different traditions to address the purposes of multiple stakeholders. Consequently, a design for CSCL-MPS research is presented that includes the use of several methods. This methodological design is used to analyse and reflect upon both a CSCL-MPS project with Colombian schools, and the identities of the participants in that project.

Keywords: Computer-Supported Collaborative Learning, Mathematical Problem-Solving, Critical Systems Thinking, Systemic Intervention, Methodological Design, Boundary Critique, Methodological Pluralism, Communities of Practice.

Introduction

In today's world, the use of information and communication technologies (ICTs) to assist learning processes is on the increase. One of the main purposes of ICT use in learning processes is to facilitate collaboration and, therefore, improve learning by means of sharing and distributing knowledge. This purpose has been pursued through a new educational paradigm called "Computer-Supported Collaborative Learning" (CSCL) (Lipponen, 2002; Lehtinen, 2003). This new educational paradigm has brought fresh theoretical and methodological challenges for researchers due to the complexity of analysing different factors in this type of learning process. For example, research has to consider analyses at both the individual and group levels; the nature of interactions between learners; students' attitudes; technological aspects; and the school's context. Considering these factors in a coherent and reflective manner is a methodological challenge for CSCL research (Dillenbourg, 1999; Daradoumis et al., 2006; De Laat et al., 2006; Stahl et al., 2006; Arbaugh et al., 2010, Arjava, 2011; Strijbos, 2011).

Currently, CSCL researchers are proposing several different methodologies to analyse CSCL processes, such as the triangulation of quantitative methods (e.g. social network analysis, statistics, surveys) with qualitative methods (e.g. interviews, content analysis) (Daradoumis et al., 2006; De Laat et al., 2006; Cho et al., 2007; Rienties et al., 2009; Gress et al., 2010). Also, some analysis of the *context* of CSCL activities is beginning to be included alongside the analyses of processes (Arnseth & Ludvigsen, 2006; Arjava, 2011). Although these methodological developments are improving the way CSCL research is being undertaken, there is still a need for further critical reflection on appropriate methodologies (Strijbos & Fischer, 2007, Gress et al., 2010; Lund, 2011), especially as very little *systemic* research has been undertaken into the current practice of CSCL and the scope for developing it into the future.

This paper offers a critique of current thinking in the CSCL research field, which we argue needs to be augmented with a "systemic intervention" approach (Midgley, 2000) if some substantial methodological challenges are to be overcome. Systemic intervention involves reflecting on boundary judgments about who and what is, or ought to be, included, excluded or marginalised in a systemic analysis. It also involves methodological pluralism: the design of methods, drawing upon resources from across the spectrum of paradigms, to approach multiple, interrelated questions regarding the problem to be analysed (Midgley, 1997, 2000). This approach implies that CSCL researchers can integrate multiple methods to aid reflection before, during, and after an intervention into CSCL processes. Note the word "intervention" here: systemic intervention is essentially systemic *action* research. In the context of CSCL, the purpose of the research is to facilitate changes in a particular CSCL process in order to improve learning amongst participants, but of course this kind of research can also produce findings of relevance to CSCL more generally.

Our paper is organised as follows. The first section presents the theoretical background and main methodological challenges of CSCL, plus the theoretical bases of Mathematical Problem-Solving (MPS). The second section presents the basis of the systemic intervention approach along with reasons why we believe this perspective can help to overcome the methodological challenges in CSCL research. The third section presents the methodological design that we consider suitable to analyse CSCL

processes, taking into account factors such as the context of application, the purpose of the learning process, and the participants' roles within a continuous cycle of reflection. The final section discusses the results of applying this methodological design in a practical case study of a CSCL-MPS process. We discuss a CSCL network called Wenaji, which operated between 2007 and 2009 in Bogotá, Colombia. Wenaji was set up as part of a larger programme of projects aimed to generate learning about how to improve CSCL-MPS processes. The methodological design proposed here is part of this learning. The purpose of the Wenaji network was to improve mathematical problem solving skills in primary school students by means of collaborative discussions aided by the use of ICT. The setting up of the Wenaji project responded to a national concern with the need to improve mathematical skills. This concern arose because of Colombian students' relatively poor performance in international mathematical tests, such as trends in international mathematics and science study (TIMSS) and programme of international student assessment (PISA) (ICFES, 2009; OECD, 2010).

CSCL Research: Theory and Methodology

This section presents the main theoretical approaches to, and definitions of, CSCL and MPS to be found in the literature. Moreover, it discusses the current, mainstream methodological designs used in CSCL research, and the methodological debates surrounding these.

What is CSCL?

CSCL refers to the use of ICTs to enhance learning through peer interaction (Stahl et al., 2006). CSCL can be offered in single or multiple geographical locations. However, it is not only about technology. According to Bielaczyc (2001), CSCL needs to be built around three levels of social infrastructure:

1) Culture (the philosophy and norms supporting an approach to learning);
2) Activities (practices); and
3) Tools (technology).

Lipponen (2002) likewise identifies a trinity of concepts: he says that CSCL has organizational, pedagogical, and technical dimensions.

The pedagogical base of CSCL is collaborative learning. According to Dillenbourg (1999), collaborative learning is a process by which individuals build knowledge, skills or attitudes occurring as the result of group interaction while solving a shared task or problem. At the heart of collaborative learning is the need to analyse learning as an *active* social process: the learners actively construct their knowledge, and interaction is important to the process of them understanding each other and generating a common language to perform a task (Salkind, 2004). In technological terms, CSCL relies mainly on the design of virtual learning environments (VLEs) to support collaborative learning activities with tools such as e-mails, discussion forums, chats, personal profiles, notes, etc. (Sheremetov & Guzmán, 2002). VLEs have a structure that consists of:

- Knowledge – all the necessary information to learn
- Collaboration – real and virtual groups
- Consulting – the teachers or tutors who give feedback
- Experimentation – the practical work of the students in a VLE
- Personal space –individual, user-specific information

Previous theoretical and practical discussions regarding the complexity of CSCL processes (see Barros-Castro & Córdoba-Pachón, 2011; Strijbos, 2011) show that the CSCL process includes different interdependent aspects: learning purpose(s); cognitive and metacognitive processes; collaborative interactions (with factors such as group composition and nature, frequency, and evolution of interactions); students' attitudes toward the CSCL process; and technological aspects of design. These discussions also show the need to consider the influence of the context of application and the participants' identities in order to promote engagement and deep learning. Taking into account these interdependent dimensions of the CSCL process, an interactive learning model has been proposed (see Barros-Castro & Córdoba-Pachón, 2011, for more details) to guide the design, analysis and assessment of CSCL processes (see figure 1).

Insert Figure 1 here.

What is MPS?

One domain where CSCL may be useful is in enhancing students' skills in Mathematical Problem-Solving (MPS). Teaching MPS involves a pedagogical strategy that supports students in learning to think mathematically. The type of thinking that is fostered through MPS involves mathematization and abstraction of situations, and developing competence in the use of mathematical tools to understand the structure of a problem in terms of patterns, conjectures and potential solutions (Schoenfeld, 1992).

In this respect, a "problem" is usually a life-like situation, involving data in the form of quantities and quantitative relationships, with a series of questions attached. "Solving the problem" means finding answers to the questions posed (Ministry of Education, 2009). Specifying a situation as a problem also implies that there is no direct, obvious way to reformulate it (Dossey et al., 2006).

In order to effectively and efficiently solve a mathematical problem, students should first understand the problem situation as well as the relationships between the known and unknown quantities before they work out the answer to the questions that are asked (Mayer, 1992; Ministry of Education, 2009). It is expected that they use resources, such as their prior mathematics knowledge, and that they employ different heuristics to understand the problem; define a strategy for solving it; find a solution; and communicate it. At a metacognitive level ("metacognition" is self-awareness of the cognitive processes that take place when learning), students need to question whether or not the strategy is the right one; change it if necessary; and invest adequate attitudinal and emotional resources into the work at hand (Schoenfeld, 1992). In addition, students need to develop techniques or strategies such as drawing figures, breaking the problem down, drawing tables, looking for patterns, making a model of the problem, and working from the solution backwards (Charles et al., 1987; Ministry of Education, 2009). In addition, MPS researchers suggest that students should interact socially in order to learn different problem-solving strategies from each other (Holton & Thomas, 2001; Hurme & Järvelä, 2005).

CSCL Methodology: Approaches and Challenges

This section presents a summary of the currently dominant methodological approaches used in CSCL research and the main challenges that CSCL researchers are facing.

Subsequent sections will offer a proposed solution in the form of a systemic intervention approach.

The Need for an Integrated Analysis of the CSCL Process

In the field of CSCL, some researchers have reflected on current methodological practices (Strijbos et al., 2004a; Arnseth & Ludvigsen, 2006; Arjava, 2011; Lund, 2011). They describe four general methodological approaches and their respective chosen methods:

Quantitative Research. Some researchers are dedicated to the use of experimental designs to analyse the impacts of certain interventions into CSCL processes. Experimental designs are supported by the use of attitudinal surveys (Dewiyanti et al., 2007); content analyses (CA) of students' messages posted in the VLE (Strijbos, 2009); social network analyses (SNA) to describe patterns of interactions with different measures for relational data (De Laat et al., 2006; Rienties et al., 2009); and final grades to evaluate the impact of certain variables on learning performance (Suthers et al., 2003).

Qualitative Research. Other researchers point out the need for qualitative research that explores the situated perspectives of actors in the CSCL process, making as few a priori assumptions as possible about what will be relevant to the research. They advocate that the researcher should remain open to surprises from engaging with the subjective and intersubjective perspectives of participants. This qualitative approach is usually supported by ethnographic methods (Strijbos & Fischer, 2007; Arjava, 2011) and interviews (De Laat et al., 2006; Pozzi et al., 2007).

Mixed Methods. This refers to the use of two or more methods that nevertheless come from the same paradigm (quantitative or qualitative). A mixed methods design involves a triangulation procedure (comparing information about the same topic derived from the use of two or more different methods) to integrate the results and explore CSCL phenomena in greater depth than a single method could achieve (Strijbos & Fischer, 2007; Rienties et al., 2009).

Hybrid Methodology. This involves the combination of methods from different research paradigms (Strijbos & Fischer, 2007). An example is the use of interviews with surveys and SNA (Zemel et al., 2009).

From these perspectives emerges a first challenge. Strijbos and Fischer (2007) claim that CSCL research needs to focus on the last two research strategies to enable deeper understandings of CSCL phenomena. They also say that it is important to document the fusion of methods and the emergence of findings, allowing researchers to learn from documented experiences. CSCL research requires long term study, with conceptual questions (rather than just technological ones), that allow theory to be linked to practice (Reeves et al., 2004). Nevertheless, although mixed and hybrid approaches increase the subtlety of analyses, some researchers recognise that they can still fail to yield truly integrated analyses that are capable of generating deeper understandings of the CSCL process within a coherent and reflective theoretical perspective (Gress et al., 2010; Strijbos, 2011).

The Need to Analyse the Context

In recent years, researchers have been discussing the need to include methods for context analysis (Arnseth & Ludvigsen, 2006; Pozzi et al., 2007; Arjava, 2011). These discussions have come about because of a lack of clarity regarding what "context" means and how to measure it (Strijbos & Fischer, 2007). Researchers have proposed a number of methods to help look at context. For example, Arjava (2011) includes content analysis and surveys, focusing on the context of perceptions of CSCL activities as revealed in on-line communications and questionnaire returns.

Another approach to the context is proposed by Lipponen et al. (2004). They present the idea of analysing the context, taking into account several dimensions of the CSCL process (cognition, metacognition, participation, and motivation); questioning the purposes of learning activities; analysing social practices from individual and group perspectives (social practices being an important aspect of context); and working in collaboration with practitioners to make sense of the CSCL process-in-context. However, these authors do not make any explicit methodological suggestions in support of the above.

Another proposal (Strijbos et al., 2004b; Strijbos, 2011) presents the need for a systematic approach. These authors propose a framework that takes into account critical contextual elements that affect interactions. In addition, De Laat et al. (2006) include a type of interview model called Critical Event Recall (CER), whereby the interviewer presents a number of events to aid recall. The researcher then reflects on his or her findings and asks, "why are the participants talking as they do?"

A final approach to analysing the context is proposed by Arnseth and Ludvigsen (2006). They present a study of what they call a "dialogic approach", focusing on how the meaning and functions of discourse, tools, and knowledge are constituted in social practices. Social interaction is the centre of analytical attention. Therefore, the idea is to analyse everyday practices and the discourses relating to those practices, taking these to be the key elements of context.

A challenge here is that, while all the above authors have identified elements of context that could be relevant to CSCL approaches, each new CSCL project will most likely have novel dimensions. Therefore new contextual variables, not previously considered, may become important. Indeed, we are sceptical of attempts to list "comprehensive" sets of contextual variables, suggesting instead that a methodological process for exploring context can be more helpful than such lists (also see Midgley et al, 2013).

The Need to Promote Critical Reflection on CSCL Purposes, Processes and Outcomes

Previous proposals made by Lipponen et al. (2004) and Arnseth & Ludvigsen (2006) take into consideration the need for linking research and practice. In line with that need, Strijbos et al. (2004a), Stahl et al. (2006), Laurillard (2009), and Strijbos (2011) have described another challenge: the lack of attention paid to the "CSCL learning perspective". In other words, the gap between the instruction and learning goal on the one hand, and methods to implement CSCL processes on the other hand. This challenge

implies both the generation of critical reflection on CSCL purposes and the evaluation of CSCL process and outcomes (Gress et al., 2010; Strijbos, 2011).

The Need to Analyse Participants' Identities

In the context of reflections and evaluations, it is important to consider the roles and identities of researchers, teachers, and other possible participants in the CSCL process, and not only the students' roles (Sarmiento & Shumar, 2010; Strijbos & De Laat, 2010). This is important because the attitudes and perspectives of the different actors can affect the learning purposes, processes, and outcomes.

Taking into account the above-mentioned challenges, the next section presents the basis for the systemic intervention approach that we argue can address these.

Systemic Intervention Framework

CSCL research needs integrated analyses, critical reflections on CSCL purposes, and analyses of context. These are all things that have been considered in the literature on Critical Systems Thinking (CST). There have been a variety of CST proposals for a critical, systemic and pluralistic approach to the design of action research (e.g. Flood and Jackson, 1991; Flood & Romm, 1996b; Jackson, 2000, 2003). However, we will focus on one particular proposal, systemic intervention, given that this is the only perspective that also focuses in some depth on agents' identities.

Systemic intervention is a CST research perspective proposed by Midgley (1997, 2000). Midgley defines systemic intervention as "purposeful action undertaken by an agent to create change in relation to reflection on boundaries" (p. 129). This definition involves a cycle as follows:

- Critique – about exploring different possible boundaries and associated values that could be employed in an analysis, and choosing between them. Dialogue between stakeholders may be important here (Ulrich, 1983), but the researcher still has a pivotal role because a level playing field in dialogue cannot be assumed.
- Judgement – Here, the idea is to judge which theories and methods might be most appropriate, given the boundaries already chosen. Midgley talks about the "creative design of methods", which involves understanding the problem situation in terms of a series of systemically interrelated research questions, each of which might need to be addressed using a different method, or part of a method. Furthermore, it allows us to mix methods from different paradigms (or even invent new methods) to address the research questions. The set of questions may evolve as events unfold and understanding of the situation develops. The interactive set of methods that emerges is usually different from (or more than) the sum of its parts (Midgley, 1990, 2000).
- Action – this involves using of the set of methods to stimulate improvement.

A distinguishing feature of this approach (already mentioned under "critique", above) is the idea of making boundary judgments. Midgley's proposal for exploring boundaries builds on prior work by Churchman (1970) and Ulrich (1983). He uses the term "boundary critique", which refers to the process of exploring who and what is, or should be, included or excluded from analysis (Midgley et al, 1998; Midgley, 2000). In

addition to looking at inclusion and exclusion, Midgley (1992, 2000) also proposes the analysis of *marginalization* as part of boundary critique: marginalization is where particular stakeholders and issues are neither fully included nor excluded from the system, and they are then subject to strong labelling and ritual treatment (Midgley, 2000; Córdoba, 2009). Regarding this issue, Foote et al., (2007) say that "Midgley (2000) talks about marginalized people and issues being made 'sacred' and 'profane' to indicate the potency of the valuing or devaluing that they are subject to" (p. 647). Figure 2 presents the model of marginalization and conflict proposed by Midgley (2000).

Insert Figure 2 here.

The basic idea of boundary critique is to reflect on different possible boundaries for analysis, and the associated values that make these boundaries adequate or not from different stakeholder perspectives. As part of this, it is important to examine the identities and roles of agents included in, marginalized by, or excluded from a social design (Midgley & Ochoa-Arias, 2001; Midgley et al, 2007). It is these identities and roles, bound up with marginalization processes, which will make a significant difference to how the action research unfolds. Therefore, boundary critique is crucial to inform judgement on appropriate methods, because identity issues and marginalisation processes need to be addressed by these methods (or at least need to be properly accounted for) if a systemic intervention is not to merely reinforce currently dominant perspectives (Midgley et al, 2007).

According to Midgley and Ochoa-Arias (2001), the systemic intervention cycle of critique, judgement and action is applied with both agents and process in mind. The general view of the cycle is detailed as follows (see Figure 3):

- *Process side*: We can begin with the identification of problematic phenomena. Here, we might find some contrasting interpretations of the problematic phenomena using boundary critique.
- Note that the problematic phenomena are interpreted in terms of what *is*, but there is also a normative dimension to each interpretation: what ought to be and the means for realising that ought. For each interpretation, the is, ought and means come together into a whole perspective on the phenomena of concern. Research methods can be chosen to deepen understanding of all or some of the perspectives that have been identified.
- After some initial reflection on two or more contrasting interpretations, it is possible to choose between them, or dialogue might create a shifting of the boundaries and the emergence of a new interpretation. Again, this learning can be supported with appropriate research methods.
- *Agents' side*: During the identification of problematic phenomena and their interpretations, the roles and identities of the agents may also appear to be problematic. Thus, interpretations regarding roles and identities have to be discussed too.
- After some initial reflections (as in the "process side"), a choice between interpretations can be made, or there may be a transformation of how the roles and/or identities of the agents are seen. Possible new roles and identities may be defined.

- The questioning of roles and identities also helps to identify new problematic phenomena. So, the cycle is re-entered on the process side.

Insert Figure 3 here.

In this cycle, a systemic intervention does not just focus attention on learning about the process, but also on the need for the agents to surface different interpretations of their identities, what these identities ought to be transformed into, and how the transformations should happen (Midgley and Ochoa-Arias, 2001; Midgley et al., 2007).

Taking into account this description of systemic intervention, it can be said that it helps us to understand how we can analyse a CSCL process. First, the idea of looking at multiple possible interpretations of the CSCL process and the agents (and in a wider sense stakeholders) of this process (designers, students, researchers, teachers, etc.) can be useful in research. Hence, we can ask who and what can be considered pertinent in the analysis as a way to question the purpose of the inquiry, the context of application and participants' identities. Second, we can use the notion of the creative design of methods to approach the different dimensions of the CSCL process (cognition, metacognition, social, motivational, and technological). In doing so, the choice and or creation of methods that can answer different questions related to the CSCL process is the means to address the challenge of producing more integrated analyses. Finally, systemic intervention also aims to generate changes in the situation studied, so learning processes and performance can be improved according to the purposes being pursued in particular cases.

The next section presents the development of a coherent and reflective methodology in terms of a generic set of questions to take into account in CSCL processes. In other words, they are questions about CSCL processes that make sense in terms of the systemic intervention approach, although in practice there is a need to translate these generic questions into specific ones relating to the particular situation being analysed. Any project-specific list of questions needs to include some related to the dimensions of the CSCL-MPS process (see figure 1). In our case, this set of questions has been used in the analysis and evaluation of a CSCL-MPS process in Bogotá, Colombia.

Methodological Design: Questions and Methods for Systemic CSCL-MPS Research

To take advantage of systemic intervention, in other words to take advantage of an exploration of different possible boundary judgments, a creative design of methods with its respective questions is required. Table 1 presents a summary of the boundary questions concerning the stakeholders and issues to be considered in a CSCL research process.

We should acknowledge some of the previous literature that has informed the development of the generic questions proposed in Table 1:

- Checkland and Scholes (1990), who propose questions to evaluate decision and implementation processes in social projects.
- Mingers (1997), who proposes questions regarding relations (i) between practitioners (agents) and intellectual resources (available theories and

methodologies), (ii) between practitioners and the problem situation, and (iii) between the problem situation and intellectual resources. Here, special attention is focused on categories i and ii; questioning the practitioners' identities, their knowledge, and their motivations, amongst other things.

- Wenger (1998, 2000), who proposes dimensions and questions to guide a design for learning in Communities of Practice (CoP).
- Midgley (2000), who proposes some questions to guide a systemic intervention (especially questions focusing on boundaries, issues, and knowledge).
- Reynolds (2001), who proposes questions to evaluate expert support in systemic improvement exercises, considering the skills that practitioners bring (or fail to bring) regarding objectivity, participation and reflection.
- Córdoba and Midgley (2008), who propose questions which are designed to make information systems research more critical.

Insert Table 1 here.

Table 1 presents two set of questions. The first set concerns agents' identities and includes their purposes, interests, roles, attitudes and interactions amongst themselves. The second set concerns the basis of the learning process in terms of purposes, notions of improvement, learning dimensions, and knowledge to be promoted. One reason for addressing all these questions is to make explicit what issues are out of the scope of the CSCL-MPS process or activities.

Some of the methods from the following methodologies and frameworks may be useful in addressing the set of questions above: Critical Systems Heuristics (CSH) (Ulrich, 1983), Soft Systems Methodology (SSM) (Checkland, 1981; Checkland & Scholes, 1990; Checkland & Poulter, 2006) and the Community of Practice (CoP) framework (Wenger, 1998, 2000). Below we explain how these could work within a systemic intervention approach.

Critical Systems Heuristics (CSH)

CSH is a framework that could suit our purpose to answer boundary questions concerning CSCL-MPS processes and agents. CSH is specifically designed to support the process of making boundary judgements (Ulrich, 1983). It helps people identify and examine boundaries used by themselves and others; debate and challenge those boundary judgments that they disagree with; and build an argument for more appropriately bounded proposals (Ulrich, 2005). CSH offers twelve questions that can be asked about what *is* the case and what *ought* to be developed (see Appendix 1). There are four basic boundary issues, each of which is addressed by three questions (adding up to the total of twelve questions). The four boundary issues are (Ulrich & Reynolds, 2010):

- Sources of motivation: where a sense of purposefulness and value comes from.
- Sources of power/control: where necessary resources and power are located.
- Sources of knowledge: where sufficient expertise and experience is assumed to be available.
- Sources of legitimacy: where social and/or legal approval comes from.

Ulrich and Reynolds (2010; p. 260) also talk about three boundary problems that need to be addressed:

- Social group or role (who should be viewed as a stakeholder?).
- Role-specific concern (what is at stake?).
- Key problems in reconciling clashes between different views on stakeholding.

There are two main purposes to CSH: to analyse current situations and to support people in challenging the boundaries of others when they disagree with them (Ulrich, 2005). Midgley (2000) has also employed CSH in the context of collaborative service design, which is particularly relevant to the development of CSCL initiatives. The CSH conceptual framework helps people uncover the purposes, values and interests of those who are involved and affected; to question the issues that are being considered; and identify those that *ought* to be considered (if they are currently being marginalised).

Soft Systems Methodology (SSM)

Synergies between CSH and other methods can be useful in the exploration of boundary questions (Midgley, 1997, 2000). In this regard, soft systems methodology (SSM) (Checkland, 1981; Checkland & Scholes, 1990; Checkland & Poulter, 2006) offers useful methods to explore the cultural features of the situation being studied. The basic idea behind SSM is to generate learning about the situation and the participants' worldviews, comparing conceptual models of human activities (what Checkland and colleagues call the "logic stream") with perceptions of the current situation (the "cultural stream"). SSM supports people in defining potential improvements, taking into account that there may well be multiple actors with different viewpoints. Moreover, it can help in identifying specific activities that need to be undertaken in the course of an intervention (Midgley, 2000) and can also help to make sense of, or support reflection upon, the flux of events and ideas in a problematic situation (Checkland & Scholes, 1990). In the case of CSCL-MPS research, the challenge of reflecting on learning purposes, processes and outcomes can be supported by some of the methods from SSM. Previous uses of SSM have shown its relevance in dealing with these kinds of issues within a systemic intervention (Midgley, 2000).

Communities of Practice (CoP)

In addition to CSH and SSM, the communities of practice (CoP) framework can support people in exploring participants' identity issues within a systemic intervention approach to CSCL-MPS research. CoP is a social learning perspective in which competence and experience within communities generates expertise or innovation based on the negotiation of meaning about the practices engaged in by the community's members in a specific domain of action (Wenger, 1998). The CoP framework sees identity as something that is built over time, taking into account internal-CoP as well as external-CoP processes, where a learning trajectory within the community is essential (Wenger, 2000). In addition, Wenger's framework suggests that it is important to see an identity as a diverse, not homogeneous, set of elements that involves roles, single community memberships, multi-memberships, cultural aspects, and different types of participation (including non-participation) (Wenger, 1998). Furthermore, the CoP framework sees identity as a by-product of the interplay between modulation of identification (different levels of engagement) and modulation of accountability (different levels of

competence). The following (from Wenger 1998, 2000) are the aspects to be considered within our methodological design for CSCL-MPS research:

- The tension between social competence (which social systems establish over time) and personal experience (which each participant has as a member of the specific social systems that he or she is in) in the evaluation of evidence of social learning (or the lack of it).
- Identity characteristics: identity can be explored considering different factors. Here, the view of identity as a learning trajectory that can take many forms, including peripheral and marginal, contributes to the process of reflecting on boundary judgments. The concept of legitimate peripheral participation (Lave & Wenger, 1991) is important in highlighting different forms of participation that can be legitimate, including quite limited ones. Besides, the idea of an identity defined by multi-membership considers the process of reconciliation between the communities in which we participate and its influence on boundary judgments.
- The modulation of identification: different levels of engagement should be studied to evaluate the identity and community building process, and the way these levels affect students' studies.
- The modulation of accountability: elements that define competence in the different constitutive elements of social learning systems should be explored to account for tensions between and within communities:
    - In terms of communities, the learning focus (joint enterprise), social capital (sense of community), and self-awareness (about shared repertoire) can be evaluated.
    - In terms of boundary processes between communities, the level of access and understanding of the problem situation (transparency), the level of adaptability in making decisions and applying them (coordination), and the level of accountability and commitment to explore multiple perspectives (negotiability) can be tracked.
    - In terms of identity dimensions, we can reflect on the depth of connections, the scope of the identity factors, and the level of proficiency to participate actively.

All the above ideas from CSH, SSM and CoP can support the generation of answers to the boundary questions in Table 1. They can promote learning by exploring multiple interpretations and options for the CSCL research, and importantly they can help in co-constructing this learning (Midgley, 2000). Figure 4 presents a summary of the methods to support CSCL-MPS research within a systemic intervention framework, using a diagramming technique from Midgley (2011). Figure 4 also integrates more traditional methods commonly used in the CSCL-MPS field. Midgley (2000) makes the point that a systemic intervention can incorporate the use of traditional quantitative and qualitative methods, but the findings from these need to be interpreted as part of the wider systemic inquiry.

Figure 4 includes previous thinking by one of the authors of this paper (Barros-Castro & Córdoba-Pachón, 2011), and this was used as the methodological design for our case study of CSCL-MPS research in Colombia (see below). However, we should insert a caveat here. The different methods proposed in figure 4 were used for two purposes:

first, to support the design and analysis of CSCL-MPS activities in our project; and second, to support reflections on those activities as well as on learning purposes and participants' identities. A description of the traditional methods from CSCL-MPS is beyond the scope of this paper (see the literature referred to earlier if you want to know more about these). The following section presents our reflections on our Colombian case study.

Insert figure 4 here.

Using the Methodological Design in a Practical Case: the *Wenaji* Project

Context and Project Description

Wenaji (2007-2009) was a MPS virtual learning network aimed at helping students improve their MPS abilities by giving them opportunities to use a diversity of MPS strategies in the context of a VLE that allowed students to work together in tackling mathematical problems. Initially, *Wenaji* involved 231 fourth-grade students and seven teachers from four Bogotá schools (one of the schools was located in a rural area, and the other three were city-based). The children were aged seven to nine and were from quite different social backgrounds (one of the schools was solely for children from low-income families, while the others drew children from a wide range of backgrounds). *Wenaji* also invited parents to participate in some initial discussions. Parents had their own website where they could learn about the project and the use of the internet with their children.

The network grouped students so that four students with heterogeneous characteristics had to work together collaboratively. Initially, the heterogeneity was based on gender and school membership. The dynamic of *Wenaji* was cyclical. The first step in the implementation phase was the application of a MPS test and a survey of attitudes towards mathematics. A post-project test and survey was applied at the end of each school year.

Every three weeks, a set of mathematical problems was loaded onto the VLE. The expected dynamics around each set of problems was as follows. The problems were expected to be discussed by the students in each group, first in the computer room, and then via the VLE when students were able to use it. After three weeks of on-line discussions, students had to present their solutions in their math class by showing their results and discussing them face-to-face with their classmates. The teacher was then expected to give feedback to the students on the process and results. This cycle was repeated eight times (during the school year there were eight sets of four problems).

During the project, monthly voluntary meetings, including teachers and researchers, were held, in order to evaluate the evolution of the project. In these meetings, teachers presented an oral report of what was happening with the VLE and the problems they and their students encountered. Additionally, the researchers presented a number of written reports related to computer-generated records of interactions, and we also discussed the problems raised by the teachers. These reports supported the reflections of the participants throughout the life of the project. Some of the reflections will be presented in the next section.

Reflections on the Project using the Questions from Table 1

Agents and Stakeholders: Participants' Identities

Interactions between teachers and students and within student groups have been considered in previous CSCL research (e.g. Dillenbourg, 1999; Daradoumis et al., 2006; De Laat et al., 2006). In this regard, the questions helped us understand that, in the *Wenaji* project, students framed their identities by reciprocity interactions; by actively bridging gaps between groups when they became apparent; and by associating themselves with different routines for engaging in mathematics discussions. Moreover, the VLE helped to generate interactions regardless of gender, although in face-to-face mathematics discussions, same gender interactions were more frequent.

Taking into account the feedback received from the students based on the surveys, meetings, and the messages sent between them in the VLE, it can be said that the students' learning trajectories were marked by overall positive changes in MPS skills and positive attitudes toward the CSCL-MPS process, but negative attitudes regarding anxiety and levels of joy. In particular, students valued this innovative way of learning mathematics (using a VLE; sharing their thoughts with their classmates via chats and forums; and discussing mathematical problems instead of just listening to a teacher and working from books). In addition, some of them perceived the project as an opportunity to challenge their own mathematics learning process, and this was the case regardless of their initial mathematics performance. However, during the intervention, their levels of anxiety increased and their levels of joy decreased. They reported that these changes came about as a result of their own reflections on the level of difficulty of the mathematics problems, their engagement, and their knowledge.

We discussed the above findings in our monthly meetings with teachers, and this led to us thinking about other stakeholders in the process. A first consideration was the inclusion of parents as clients of the project. We reflected on the possibility that parents' attitudes to, knowledge of, and perceptions about the CSCL-MPS process might affect their children's performance. We suggested that, as clients of the system, they could learn how to motivate their children more effectively. Thus, in the *Wenaji* project, parents were invited to a meeting. However, it did not go quite as we expected. Some of the parents complained about the time their children had to invest and the level of difficulty of the project's activities. In this regard, parents' identities were analysed as part of our research, and it seems that these were framed by their own experiences of mathematics education and the use of ICTs in education more generally. They had learned their own mathematics skills through the completion of written exercises, so the whole problem-based focus of MPS was hard for them to follow. Moreover, there had been a lack of discussion between teachers, researchers and parents, so it was little wonder that the latter struggled to understand the project purposes. As a result, parents' identities were mostly framed as non-participating. With respect to parents' roles, we came to the conclusion that a legitimate peripheral identity should be promoted by discussing with parents the project's implications. Thus, parents could become part of the project in peripheral, valued roles instead of being marginalized.

A second consideration concerned the teachers' roles in *Wenaji*. Teachers were considered clients of the system; therefore, continuous support from teachers to generate mathematical discussions and CSCL monitoring skills was promoted in the monthly meetings. Nevertheless, some teachers (4 out of 7) were not involved as intended. In particular, they were not interested in changing their own practices regarding traditional mathematics learning, and the researchers could not attain sufficient engagement with them to challenge this. These teachers had a learning trajectory based on a low level of understanding of the project enterprise, a low level of engagement, and a lack of ability to use the available resources. However, in contrast, some other teachers embraced an identity of active participant, taking full advantage of the project. Here, the questions regarding stakeholders' interests made us realise that we had not sufficiently considered the need to negotiate the teachers' interests with those interests and purposes that the project was pursuing. In addition, although the *Wenaji* project saw the teachers as key clients, it did not put in place sufficient resources to track the participation of teachers and address non-participation quickly through constructive engagement. Finally, the relevance of teachers' professional experience in the classroom was not sufficiently considered. It was assumed that the teachers' purposes, as pursued in the classroom, could be aligned with the project purposes and activities, and that success would just be a matter of effective coordination. However, coordination was not enough; there was insufficient dialogue to create bridges between classroom practices and project activities, and to generate accountability for the project process and outcomes.

Considering the researchers' identities, we saw ourselves as social innovators of mathematical learning in the communities where we were intervening. In undertaking our intervention, we wanted to generate an innovative mathematics learning environment (with the CSCL-MPS process as a pedagogical strategy). Here, our identity was framed by two things: first, the ability to coordinate activities and generate a balance between different communities in which we belong (as project researchers, university and school teachers, and people with our own academic interests); and second, a *lack* of ability to generate strong teacher alignments to the project purposes due to the identity issues presented earlier. However, we also experienced a learning trajectory in terms of the project purposes and the classroom dynamics. These reflections (using the questions) can be seen as part of this learning trajectory that frames our identity as researchers.

General Issues: Context of Application, Learning Purposes, Processes and Outcomes

We identified a significant conflict between the different mathematics learning approaches practiced by teachers, researchers, and parents. As shown in Figure 5, some individuals claimed that mathematics learning must be supported by the traditional approach of lectures and classroom exercises. This group of people was concerned with the level of difficulty proposed by other methods such as CSCL-MPS. Other individuals claimed that, to generate deep mathematical learning, innovative methods were required, making the inclusion of CSCL activities to support face-to-face interactions and MPS to support mathematics education appropriate strategies.

Insert figure 5 here.

In addition to this conflict, a related tension was found (see Figure 6). Using a VLE to support CSCL-MPS activities created two different foci of attention. One group pointed out that improvement should be achieved by promoting mathematical discussions in the VLE and positive attitudes towards the project. They were focused on the collaboration and attitudinal aspect of the learning process. Another group pointed out that improvement should be achieved by promoting *effective teaching and learning strategies* using the VLE. This group was focused on the cognition and metacognition aspects of the learning process. This tension relates to discussions about which dimensions to take into account in the CSCL-MPS process. Although collaboration is the pedagogical foundation of CSCL, this dimension is not always emphasised sufficiently in learning processes like the *Wenaji* project. Of course, cognition can be triggered by collaborative interactions, so collaboration and cognition don't have to be seen as mutually exclusive: it is not a case of having to choose a focus on one rather than the other, although the *Wenaji* participants polarised into two camps as if this were the case. Here, it is clear that systemic discussions about the dimensions and their interdependences could be valuable in action research on CSCL-MPS processes, to move people beyond artificial binaries.

Insert figure 6 here.

The previous two tensions impacted on how people judged which methods should be chosen to account for improvement, and whether the purposes of the project had been fulfilled (see figure 7). Those advocating for collaboration-based learning viewed the VLE as primarily a medium for social networking, so thought that progress should be tracked using methods of social network analysis and content analysis. SNA and CA methods focus on tracking the learning *processes*. Furthermore, these methods were used to support the analysis of participants' identities by tracking the evolution of individual and group trajectories and analysing the work of participants whose role was to bridge the gaps between groups. On the other hand, cognition-based learning is based on face-to-face classes, and performance is measured using standardised tests of students. Mathematics tests measure effectiveness in terms of the *content* of students' learning. In appreciating this conflict over measures of improvement, we quickly realised that both types of measure were going to be necessary because we needed to be able to build bridges between teachers who were enthusiastic about CSCL-MPS, and needed to know that the social networking aspect was working, and those who were more focused on traditional teaching in the classroom, who needed to know that CSCL does actually improve mathematical cognition.

Insert figure 7 here.

Finally, Figure 8 presents another source of conflict that involves learning purposes, contextual factors and identity issues. One school decided to drop out of the project right in the middle of its implementation. The reason was that the school wanted to prepare its students for a national test that evaluates mathematics performance. They wanted short-term solutions for mathematics education problems, and considered the project to be a time consuming distraction. This was such an emotionally charged issue for the administrators making the decision to withdraw that they would not even discuss it with the project.

Insert figure 8 here.

Conclusions

This paper has presented a proposal to overcome CSCL research challenges regarding the lack of integrated analyses and the need for greater critical reflection on learning purposes, processes, outcomes, stakeholders' identities and context of application. Our methodological design was based on a systemic intervention approach, taking advantage of the fact it involves a reflection on agents and issues to be included, excluded or marginalized. The proposal also consists of a set of interrelated questions with respect to making boundary reflections on general CSCL issues and agents' and stakeholders' identities. These questions were examined with the support of a number of systems methods and the CoP conceptual framework (especially in terms of identity). We recommend the use of this set of questions (Table 1) in a generic form, but also propose that specific questions related to the design and implementation of a CSCL-MPS process, considering different learning dimensions (and their interdependences), should be asked depending on the specifics of the intervention in focus. . We argue that this methodological design can help in the study of CSCL-MPS issues that have not been completely addressed by traditional approaches in this field.

The methodological design for CSCL-MPS research was implemented in the evaluation of a primary school project in Colombia called *Wenaji*. In that case, boundary reflections on identity and CSCL-MPS issues supported the identification of different sources of conflict, including tensions between people advocating for different learning approaches, purposes, environments, and methods to evaluate learning. Different attitudes, roles and levels of participation and competences also framed the stakeholders' identities in relation to these foci of conflict. This kind of analysis is essential if we are going to better understand the social-systemic dynamics that surround the implementation of CSCL-MPS projects.

In general, this methodological design helps us identify the need to consider different actors with different levels of participation and different identities. It is important to acknowledge the impact of different practices (experiences and competences) among and between teachers, researchers, parents, and students. Also, implementing the methodological design involves a continuous open dialogue (i.e. a process of questioning boundaries) between teachers and researchers to share, track, and challenge different practices and to negotiate their values. We argue that this type of methodological design can contribute to the generation of deeper understandings, complementing more traditional evaluations of CSCL-MPS processes.

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The 12 critically heuristic boundary questions in the *is* mode	The 12 critically heuristic boundary questions in the *ought* mode
(1) Who is the actual *client* of the system design, i.e. who belongs to the group of those whose purposes (interests and values) are served, in distinction to those who do not benefit but may have to bear the costs or other disadvantages?	(1) Who ought to be the *client* (beneficiary) of the system to be designed or improved?
(2) What is the actual *purpose* of the system design, as being measured not in terms of declared intentions of the involved but in terms of the actual consequences?	(2) What ought to be the *purpose* of the system, i.e. what goal states ought the system be able to achieve so as to serve the client?
(3) What, judged by the design's consequences, is its built in *measure of success*?	(3) What ought to be the system's *measure of success* (or improvement)?
(4) Who is actually the *decision taker*, i.e. who can actually change the measure of success?	(4) Who ought to be the *decision taker*, i.e. have the power to change the system's measure of improvement?
(5) What *conditions* of successful planning and implementation of the system are really controlled by the decision taker?	(5) What *components* (resources and constraints) of the system ought to be controlled by the decision taker?
(6) What conditions are *not* controlled by the decision taker, i.e. what represents *"environment"* to him?	(6) What resources and conditions ought to be part of the system's *environment*, i.e. not be controlled by the system's decision taker?
(7) Who is actually involved as *planner*?	(7) Who ought to be involved as *designer* of the system?
(8) Who is involved as *"expert"*, of what kind is his expertise, what role does he actually play?	(8) What kind of *expertise* ought to flow into the design of the system, i.e. who ought to be considered an expert and what should be his role?
(9) Where do the involved see the *guarantee* that their planning will be successful? (E.g. in the theoretical competence of experts? In consensus among experts? In the validity of empirical data? In the relevance of mathematical models or computer simulations? In political support on the part of interest groups? In the experience and intuition of the involved?, etc.). Can these assumed guarantors secure the design's success, or are they false guarantors?	(9) Who ought to be the *guarantor* of the system, i.e. where ought the designer seek the guarantee that his design will be implemented and will prove successful, judged by the system's measure of success (or improvement)?
(10) Who among the involved *witnesses* represents the concerns of the affected? Who is or may be affected without being involved?	(10) Who ought to belong to the *witnesses* representing the concerns of the citizens that will or might be affected by the design of the system? That is to say, who among the affected ought to get involved?
(11) Are the affected given an opportunity to *emancipate* themselves from the experts and to take their fate into their own hands, or do the experts determine what is right for them, what quality of life means to them, etc? That is to say, are the affected used merely as means for the purposes of others, or are they also treated as "ends in themselves" (Kant), as belonging to the client?	(11) To what degree and in what way ought the affected be given the chance of *emancipation* from the premises and promises of the involved?
(12) What *world view* is actually underlying the design of the system? Is it the world view of (some of) the involved or (some of) the affected?	(12) Upon what *world views* of either the involved or the affected ought the system's design be based?

Appendix 1: The 12 critically heuristic boundary questions in the is and ought modes (after Ulrich, 1986).

	Boundary Questions to be Considered in CSCL-MPS
Agents and Stakeholders: Participants' identities	• Who should be considered as agents and stakeholders? • How can the identities of the agents and stakeholders be analyzed? • What are their roles, purposes, values, and interests in this intervention? • What kinds of knowledge do the agents and stakeholders have? • What attitudes do the stakeholders have? • How can we monitor and/or challenge those attitudes/perceptions? • Are they accountable for their decisions? • Do they participate in an open dialogue about the intervention? • Do they participate in an environment (beyond the immediate intervention) that enables mutual understanding, coordination and reflection between stakeholders? How can we generate that environment?
General Issues: Learning purposes, process, outcomes and context of application	• What are the purposes of this intervention? • What are the dimensions of this CSCL process? • How can these dimensions and the relation between learning purpose, process, and outcomes be analyzed? • What is the notion of improvement for this intervention? • Who decides what types of knowledge are to be promoted? • What are the reasons for starting a CSCL process? • What kinds of rhythm and shifts of focus will allow learning and teaching to inform each other? • What are the mechanisms by which emergent patterns can be perceived and added to the learning process? • What considerations have to be taken into account regarding the context of the application of CSCL activities (i.e. technological access, different socio-economical levels of participants, class dynamics)?

Table 1: Boundary Questions for a CSCL-MPS Process.

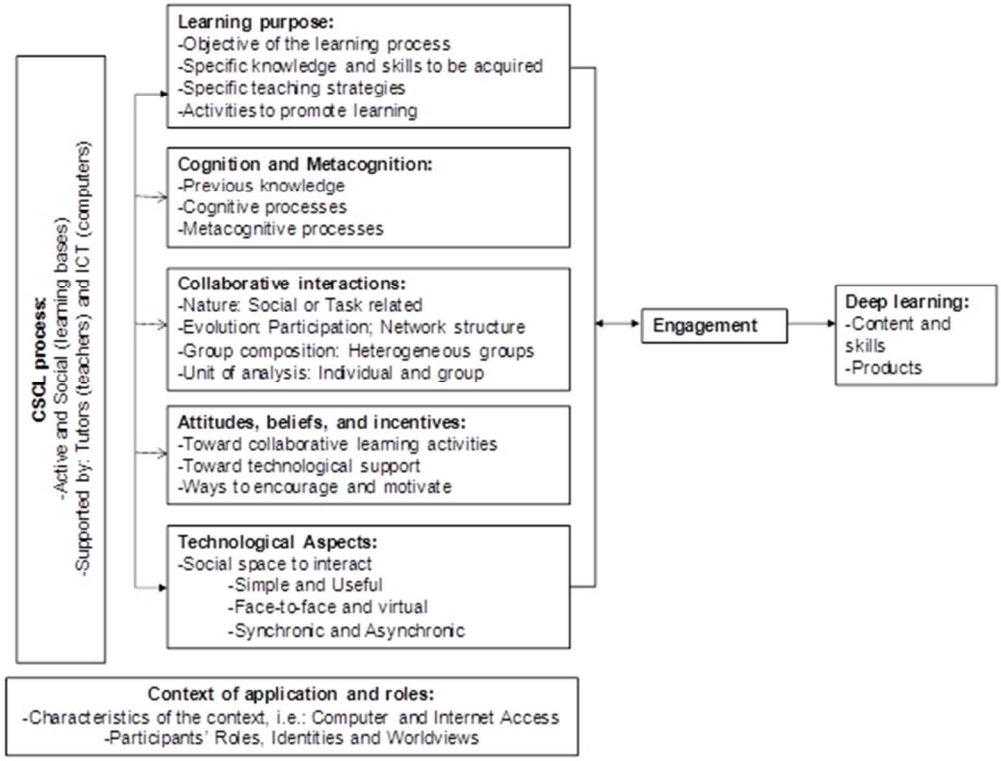

Figure 1: Model of the interactive dimensions of the CSCL process (adapted from Barros & Córdoba, 2011).
158x120mm (96 x 96 DPI)

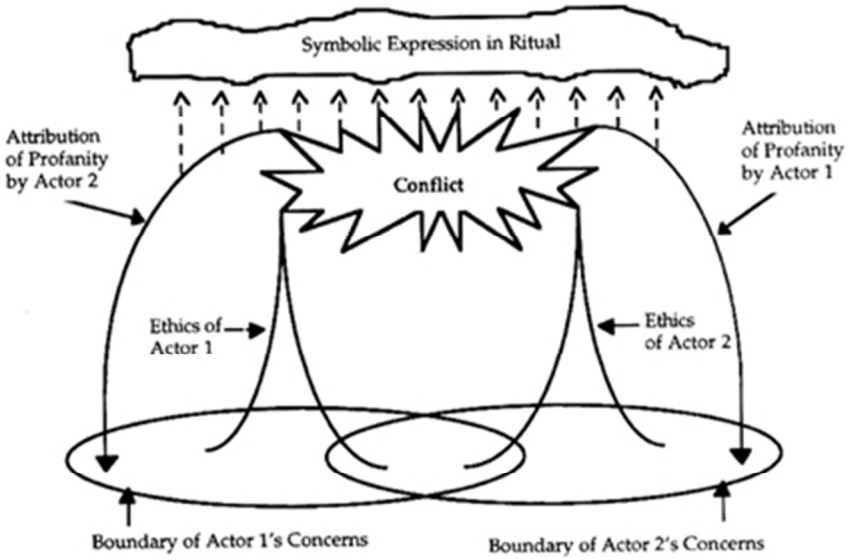

Figure 2: Model of Overlapping Stakeholder Concerns, with Attribution of Profanity (from Midgley, 2000, p. 154).
112x78mm (96 x 96 DPI)

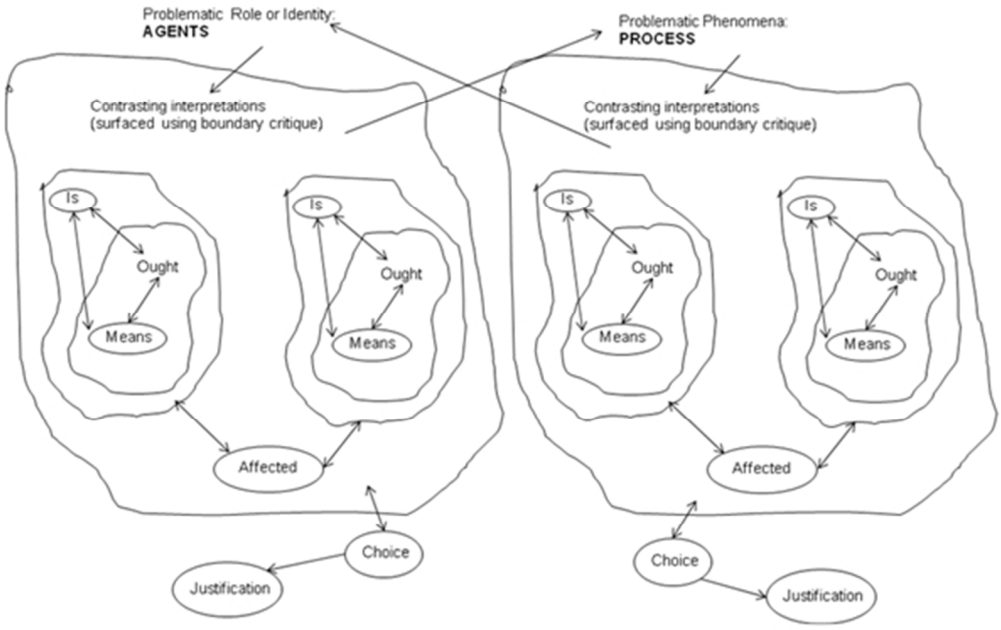

Figure 3: Systemic Intervention (adapted from Midgley & Ochoa-Arias, 2001).
157x99mm (96 x 96 DPI)

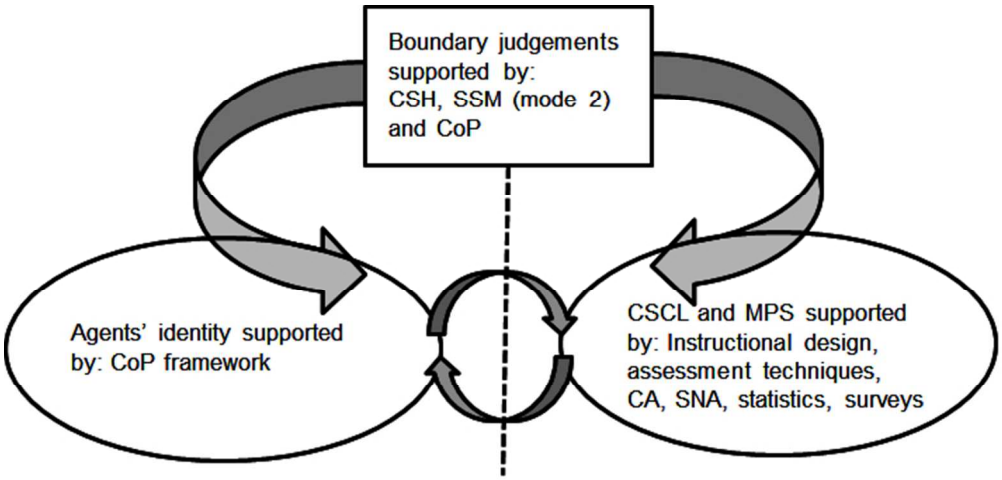

Figure 4: Methods to Support CSCL-MPS Research within a Systemic Intervention Approach (adapted from Midgley, 2011).
188x89mm (96 x 96 DPI)

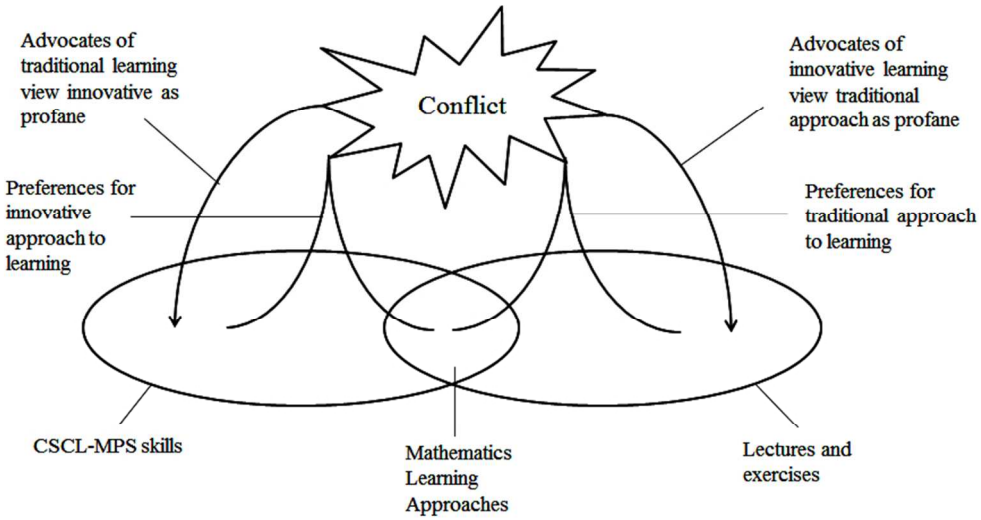

Figure 5: Mathematics Learning Approaches (using the diagramming convention from Midgley, 2000).
233x121mm (96 x 96 DPI)

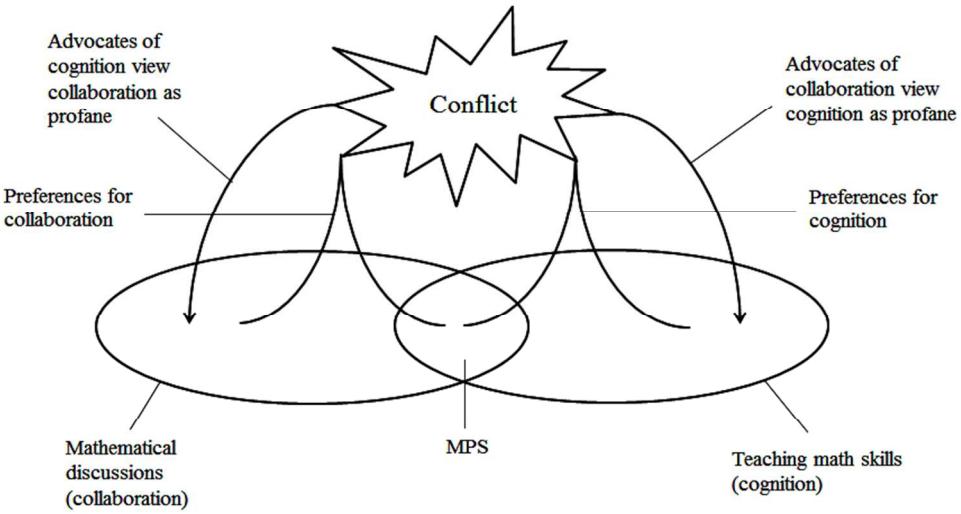

Figure 6: Purposes and Improvement.
236x122mm (96 x 96 DPI)

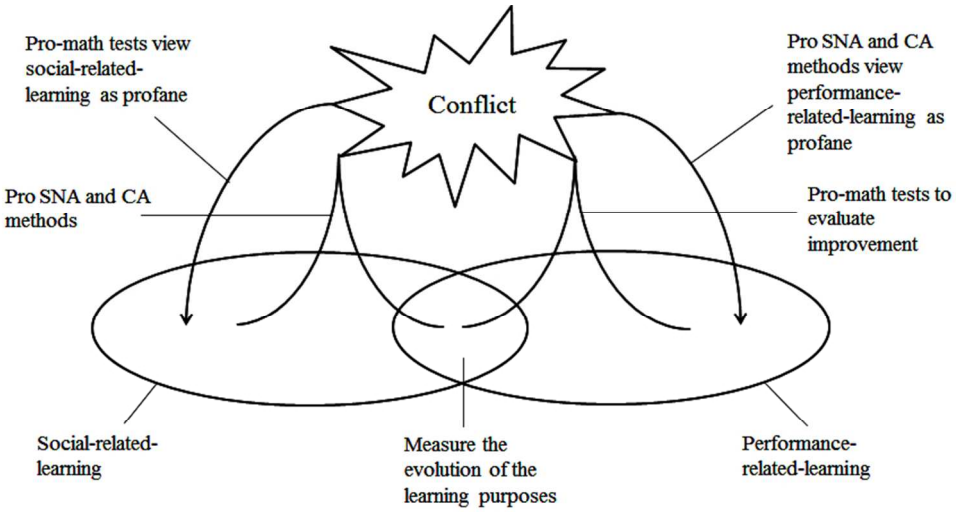

Figure 7: Methods used to measure performance.
234x121mm (96 x 96 DPI)

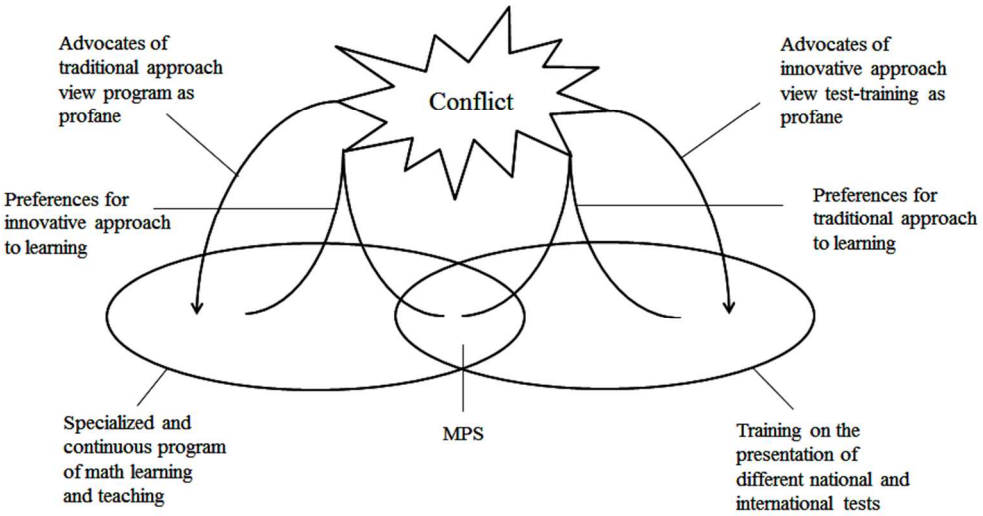

Figure 8: Promotion of High Level MPS Abilities.
244x127mm (96 x 96 DPI)