

THE UNIVERSITY OF HULL

**FLEXIBLE VIRTUAL LEARNING ENVIRONMENTS:  
A SCHEMA-DRIVEN APPROACH USING SEMANTIC  
WEB CONCEPTS**

being a Thesis submitted for the Degree of

Doctor of Philosophy

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by

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## *Abstract*

Flexible e-learning refers to an intelligent educational mechanism that focuses on simulating and improving traditional education as far as possible on the Web by integrating various electronic approaches, technologies, and equipment. This mechanism aims to promote the personalized development and management of e-learning Web services and applications. The main value of this method is that it provides high-powered individualization in pedagogy for students and staff.

Here, the thesis mainly studied three problems in meeting the practical requirements of users in education. The first question is how a range of teaching styles (e.g. command and guided discovery) can be supported. The second one is how varieties of instructional processes can be authored. The third question is how these processes can be controlled by learners and educators in terms of their personalized needs during the execution of instruction.

In this research, through investigating the existing e-learning approaches and technologies, the main technical problems of current virtual learning environments (VLEs) were analyzed. Next, by using the Semantic Web concepts as well as relevant standards, a schema-driven approach was created. This method can support users' individualized operations in the Web-based education. Then, a flexible e-learning system based on the approach was designed and implemented to map a range of extensive didactic paradigms. Finally, a case study was completed to evaluate the research results. The main findings of the assessment were that the flexible VLE implemented a range of teaching styles and the personalized creation and control of educational processes.

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## *Publications*

1. Lipeng Wen, Mike Brayshaw, July 2007, *An Individualized E-Learning Web Services Prototype*, International Journal of System and Information Sciences Notes, Volume 1, Issue 1, Pages: 29-33.
2. Lipeng Wen, Chris Jesshope, August 2004, *A General Learning Management System Based on Schema-Driven Methodology*, Proceedings of the 4th IEEE International Conference on Advanced Learning Technologies, Joensuu, Finland, Pages: 633-635.
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## ***Chapter 1 Introduction to this Research***

This chapter takes a general view of this research and consists of five sections. The first section shows the broad picture of research. The second section represents the hypothesis and aim of the research. The third section presents the practical problems and research values. The fourth one discusses the methodology used in this research. The final part shows the outline of the thesis to readers.

### **1.1. Research Broad Picture**

This research focuses on implementing the flexible management of e-learning Web services and applications to meet a range of practical requirements of students and staff. Flexible e-learning refers to the flexible learning [1] on the Web, which uses electronic approaches, technologies, and devices to support the individualized requirements of users. It is a personalized e-learning mechanism, which can support a range of teaching styles. In detail, it can implement the individualized creation of educational processes. Furthermore, during the execution of Web-based learning, the personalized control of learning units and processes can be completed. In this thesis, the concrete instance of flexible e-learning is a flexible virtual learning environment.

Here learning units [2] can be defined as digital resources that can be reused and shared in virtual learning environments, such as a lecture, a presentation, an online book, a web page, an exam, or the collection of them. In this research, learning units are regarded as learning content (learning objects), learning content packages, learning resources or learning materials. A learning content package refers to the aggregation of special learning content [3], such as a collection of six lectures, one presentation, two tests, and a Q and A. Learning resources [4] also named learning materials are defined as messages used in learning procedures. Learning units can be presented in a variety of medias and formats, such as in audio, video, Word, web page, PDF, picture, or combinations of them.

A learning process [5] is the statement of an individualized learning procedure, which is authored to facilitate learners to master the indicated knowledge, experiences, and skills. In the thesis, learning activities are defined as small learning processes. In general, learning processes including relevant learning units are modular and reused based on computer technologies such as programming languages and web services technologies.

### **1.2. Research Hypothesis and Aim**

In this research, the hypothesis is that flexible e-learning could be implemented to support a range of didactic paradigms. In terms of the needs of students and teachers, the technical solution would be implemented by using computer technologies and approaches. Through building and demonstrating a flexible e-learning system, the functions of the system would be shown to users, such as the personalized management of e-learning Web services and applications.

The research aim is to build a tool to present the feasibility of flexible e-learning. The theoretical model and technical architecture of this e-learning system would be established. Via the application of information and communication technologies to education, the e-learning system would be implemented on the Web. Then by using the means of case study and comparison, the potential advantages of the flexible e-learning mechanism could be explored.

### **1.3. The Research Questions and Values**

#### **1.3.1. The Research Questions**

In general, different students have different background knowledge, learning aims, learning results, and other personal differences. Especially in terms of the changes of learners' circumstances, they may wish to coordinate their learning processes during executing the procedures. Furthermore, staff may need to manage and control students' learning procedures according to their personal demands. It means that varieties of requirements in education need to be supported on the Web. So a central task of scientists in the e-learning area is to meet the individualized needs of users as far as possible by using electronic approaches, technologies, and equipments.

In this research, the main problems derived from the practical demands of instruction using a computer can be described as follows:

**Pedagogy:** How to support a range of teaching styles? In the actual environment of education, a set of teaching styles are used by learners and teachers, such as command, self pace, and guided discovery patterns (Chapter 2). It is very important for e-learning systems to support users to create and perform their preferred pedagogy styles. Over the years, a number of methodologies have been proposed to guide this process from Skinnerian strictness to open ended discovery learning. No one theory is embraced here instead we provide a platform to implement a range of such theories. In this research, the supporting of a range of teaching manners will be shown by integrating computer approaches and technologies.

**Content:** How to support varieties of instructional processes? In the real world of education, different educational processes are used by students and staff according to their personalized demands (Chapter 2). For example, there are a lot of different starting points of instruction for users to do their particular educational procedures. Also various roads for completing their individual instructional processes are requested by teachers and learners. It is very helpful to provide the broad avenues for instruction in terms of the requirements of users. In detail, various social and

emotional needs can be met, and users can find the most appropriate approaches to accomplish their tasks. This research will plan to implement a tool to provide the ability for learners and/or teachers to design their personalized instructional procedures.

**Process:** How to control educational processes during their execution in terms of the changes of practical requirements of students and staff? According to the learning results and/or other changes of users, they may want to coordinate their teaching and learning processes during running (Chapter 2). For instance, some learners may need to return to the previous learning units in processes as they cannot pass assignments or tests. Or during execution, some students may think they have already had a sound understanding about what they are learning (e.g. a foreign language). So they may wish to directly sit an exam (e.g. academic English test) without doing the preceding learning units. If they can pass this test, they will save a lot of time and money as they do not need to do further learning in the subject. If they are not successful, they still can return to the omitted learning units and then take this exam again. All of them require instructional procedures to be coordinated during their running, which will be achieved in this research.

### **1.3.2. The Research Values**

Through solving these problems, flexibility should be provided to teachers and learners. That is, the individualized needs of users in the e-learning area can be met as far as possible, which makes them much more user-centred in doing their instruction tasks on the Web under educational theories (Chapter 2). Also it should greatly promote the uptake of personalized e-learning Web services and applications in the world. Existing e-learning Web services and applications cannot meet the practical requirements of users mentioned above, which makes it difficult to popularize the e-learning mechanism. By removing this rigidity, we hope to make Web-based e-learning more approachable and amenable. Specifically, a range of teaching styles should be built according to the needs of tutor and tutee. Furthermore, the personalized educational processes should be created before those involved start their pedagogical endeavours. During the execution of learning, they should be able to coordinate their instructional procedures in terms of their changes of requirements. All of these techniques support teachers and learners to have a larger degree of freedom in doing their individualized teaching and learning on the Internet. Thus users should hopefully be much more engaged in the personalized designing,

performing, and controlling of the Web-based educational patterns, contents, and processes.

Different students and staff may have different interests in flexibility. Some users may like this option, and others may do not care about it. Metaphorically some people like to drive cars while others choose to take trains. Both of these requirements should be met. So it is still valuable to provide flexibility in the e-learning area. Furthermore, this research can support not only individual demands (flexibility) but also common things (the conjunct needs of all students). We support both of the choices of driving cars and taking trains.

#### **1.4. Research Methodology**

In this research, the practical requirements of educators and learners in the area of instruction were studied and the main problems were identified. Next, existing e-learning systems were investigated and a set of technical issues with them was identified. Then, through integrating some appropriate computer approaches and technologies, a method was produced to deal with the technical problems. Based on the method, a tool was designed and implemented, which can provide high-powered functionalities for teachers and learners to meet their personalized demands. The case studies and comparisons were undertaken, in order to demonstrate the efficacy of this approach. Finally, the conclusions show readers the contributions achieved here, what has been learnt, reflection on this research, and the future work.

#### **1.5. Thesis Outline**

The document is made up of nine chapters. The first chapter views the high-level things of this thesis, such as the broad picture and the research questions. Chapter 2 discusses the underlying theories and the actual needs of the research in detail. Chapter 3 analyzes the functionality and usability of existing e-learning systems, the Semantic Web concepts, and the standards involved in this research. Also it represented the technical problems. The fourth chapter describes the high-level model of the schema-driven approach created by using the Semantic Web technologies. Chapter 5 discusses the functions of the main building blocks in this approach. Chapter 6 documents the design of a flexible virtual learning environment based on the schema-driven framework. Chapter 7 describes the implementation of a prototype of this e-learning system. The eighth chapter discusses the evaluation carried out. The final chapter summarizes the achievements, reflections on the research process and methodology, and future study work.

## ***Chapter 2 Humans and Learning***

In this chapter, a set of educational theories and approaches are analyzed based on the practical requirements of humans. The chapter is divided into four sections. The first section investigates three theoretical basis in education. The second one represents and discusses a range of instructional styles. The third part makes an analysis of the needs of students and staff in building various instructional processes. The final section describes the demands of the individualized control of learning processes during execution.

## **2.1. Theoretical Basis**

### **2.1.1. Instruction**

Instruction refers to a mechanism that can support the communication or transfer of knowledge to learners with an efficient and effective pattern as far as possible [5]. In practical processes of learning, individuals have different background knowledge and learning aims, use different types of learning materials, spend different learning time with different learning speeds, use different levels of learning content, operate learning resources in different ways, have deep or surface understanding on learning materials, need the supervision of teachers in different ways, learn in different schedules, and obtain different learning results [6] [7]. It means that varieties of procedures of learning are developed and performed by staff and learners. Through studying the variation among human in the area of education, a set of learning theories have been developed and summarized based on the demands of users such as learner control and instructor management [8].

A learning theory is a general mechanism by which a set of factors observed and derived from various learning processes are used to develop high-level models of human learning [8] [9] [10]. The main value of learning theories is to help instructors and learners to have a good understanding about the process of learning, which can facilitate users to predict, design, perform, and coordinate their personalized instructional behaviours. An example of this is how learning occurs from all kinds of practical procedures (e.g. problem-based learning [11] or collaborative discovery learning [12]), and how to promote the learning itself (e.g. establishing a series of teaching styles to increase the efficiency of learning as far as possible [13]).

### **2.1.2. Basic Learning Theories**

There are a number of learning strategies that have already been produced and modified in the last one hundred years, such as conceptual analysis, computational, and connectionist [14]. However, in this section, only the basic learning theories (behaviourism, cognitivism, and constructivism) are discussed as they have greatest influence in the development and improvement of educational rules and processes [15]. For example, the instructional patterns and procedures analyzed in this thesis have been built and improved under the guidance of the basic theories (see the following paragraphs and section 2.1.3.). The detailed information about these strategies is presented below, with a focus of definitions, main authors, advantages, and disadvantages of the three theories, and the similar and different ideas of the authors of these theories in studying human instruction.

**Behaviourism** [16] [17] [18] is a generic understanding of human learning that operates on a principle of stimulus and response, which focuses on the investigation of overt behaviours that can be observed and measured. All behaviours caused by external stimuli (e.g. operant conditioning) can be explained without the need to consider internal mental states or consciousness. The primary value of this theory is that instructional objectives can be achieved by sequencing and reinforcing the changes in human behaviours during instructional procedures such as programmed learning [19]. It means that behaviourism manners can be helpful for people who are not interested in a topic, lack of desire to perform learning tasks, or do not expend effort in learning. For instance, the command teaching style is used to direct the learning of children in primary and secondary school, which is induced through compulsory step-by-step instruction (section 2.2.1.). In order to implement the approach of behaviourism, varieties of methods tried by experimenters should be checked to see whether they are useful or not in modifying the behaviours of the selected objects. Next, according to the observable changes in behaviours, some methods are proven to be much more effective than others in changing certain behaviour. Then, an appropriate behavioural pattern is created over aggregating these helpful methods. Finally, this pattern will be repeated on an object in an experiment until it becomes automatic.

The detailed information of four contributors to the theory of behaviourism is discussed as follows:

- Pavlov is very famous in studying classical conditioning (a reflexive, compulsory, repeated, and automatic type of learning) in which a conditioned stimulus acquires the capacity to evoke a conditioned response that was originally evoked by another unconditioned stimulus [20]. Classical conditioning presented by Pavlov's experiments with dogs is a kind of associative learning that may indicate how humans obtain knowledge and skills through creating new associations among events. Another aspect of associative learning is operant conditioning (see the following section: Skinner). Pavlov rings the bell (conditioned stimulus) to cause the dog to eat the food (conditioned response) that has previously been done by the dog automatically and naturally [21]. The implication of Pavlov's research on educational technology is that human learning can be done in a way continually reinforcing the conditioned stimulus

on people behaviours over their natural cognitive processes, which can increase the efficiency of the instruction on learners with disabilities [22].

- Skinner's theory investigated learning procedures by using the methods of reward and punishment [23]. Like Pavlov, Skinner processed the changes in observable behaviours without considering any processes occurring in the mind. The main difference between Pavlov and Skinner is that the latter indicated the principles about how voluntary behaviours can be encouraged by using all kinds of approaches (e.g. good grades or money) in various environments (e.g. education and medicine) [24] [25]. This is regarded as operant conditioning that can establish varieties of bindings between conditioned response (learner's behaviours) and conditioned stimulus (reward and/or punishment) although these associations did not exist before. In applying this theory to education, instructors can use assessment and positive criticism to develop the relationships between the specific knowledge or skills and people's desires or dislikes, which is able to improve the ability of managing learners' behaviours [26].
- Gagne categorized the levels of learning in terms of the different types of actual instruction, in which nine events of instruction were also discussed in how to build appropriate learning procedures (e.g. proper stimulus, responses, feedback, and media) for learners on the different layers in designing instruction [27] [28]. In detail, five major classifications of learning are identified by Gagne: intellectual skills, cognitive strategies, motor skills and attitudes, and verbal information. As a layer of learning, intellectual skills suggests people classify and assemble their learning tasks in terms of the degrees of the complexity of tasks: stimulus recognition, response generation, procedure following, terminology, discriminations, concept formation, rule application, and problem solving. Also in order to master cognitive strategies, Gagne suggested providing the chances for learners to develop new practical solutions to problems and to be exposed to attitudes, credible role models, and/or persuasive arguments [27]. Furthermore, the theory analyzes nine instructional events and corresponding cognitive processes: gaining attention (reception), informing learners of the objective (expectancy), stimulating recall of prior learning (retrieval), presenting the stimulus (selective perception), providing learning guidance (semantic encoding), eliciting performance (responding), providing feedback (reinforcement), assessing performance (retrieval), enhancing retention and transfer (generalization) [28]. In detail, the event of gaining attention refers to

collecting learners' interests into their subjects, such as presenting how delicious it is to a child when teaching him/her to cook fish. Also informing learners of the objective lets learners know what they will be learning [27]. Gagne's learning hierarchical framework contributed a mechanism of instructional design which can identify prerequisites (different internal and external conditions for each level of learning) through completing educational task analysis [29]. This mechanism is a huge convenience for instructors to design a variety of instructional sequences as well as the related nine instructional events with different content. Thus, human's individualized requirements in different learning outcomes and levels can be matched with [29] [30].

- Bandura's social learning theory indicates that people learn from one another by observation, imitation, and modelling, which crosses the frameworks of both behaviourism and cognitivism because it involves the aspects of attention, memory, and motivation [31] [32]. In general, not all of reinforced behaviours are imitated by children, such as some pupils were always late for school and others were not. In addition, new behaviours may be modelled by children after their first observation without reinforcements on the behaviours. For example, one student can do similar things through observing and imitating others' behaviour in the same group. These social behaviours cannot be explained by the traditional operant conditioning (e.g. Skinner) that children should perform and receive reinforcements before being able to learn. During several years of investigating social learning, Bandura found that there are interactions between three essential building blocks of social learning: environment, behaviour, and one's psychological processes (e.g. thinking other people's ideas in the mind and talking with them in a language) [31]. In detail, a person learns through observing others' behaviours and attitudes, and outcomes of those behaviours. In order to effectively model these interactions in observational learning, there are four components that should be considered: attention, retention, reproduction, and motivation [33]. The amount of attention paid will be increased or decreased under the influence of all kinds of factors such as modelled events (e.g. distinctiveness, affective valence, complexity, prevalence, functional value) and observer characteristics (sensory capacities, arousal level, perceptual set, past reinforcement). Reproduction refers to reproducing the images of the observed behaviours in the internal mental processes of the mind of observer via physical capabilities, self-observation of reproduction, accuracy of feedback. The main

achievement of the study is that Bandura accomplished a social learning mechanism based on the features of both behaviourism and cognitivism, which can direct humans to acquire what they want by continuous reciprocal interactions between cognitive, behavioural, and environmental influences [33] [34]. As this theory lets teachers have a good understanding of the relationships between the behaviours and cognitive processes of learners, so it can greatly support staff to create various instructional designs in terms of the different situations of students [35].

The main strength and weakness of behaviourism are described as follows [19] [36] [37]:

- In learning processes designed according to this theory, a learner is focused on a clear aim through motivating the learner with a variety of stimulus. Furthermore, the learning principle causes people to make responses in a practical environment, which is helpful for them to achieve their aims. An example of this is that boxers are conditioned and trained to respond to their rivals, such as how to attack and defend. When fighting in a match, one participant will automatically perform the responses to the behaviours of the competitor. This is essential for a boxer to be successful, as during a competition there is no time for a person to think how to deal with the rival's action.
- The stimulus for the correct response does not occur in some situations, in which learners may find that they cannot respond. Here, the aimed knowledge and skills are not acquired by people because it is very difficult to produce appropriate environments that can be used to create stimulus. For instance, as it is difficult to imitate the environment of earthquake, so the proper stimulus can not be created. When people were in the situation of earthquake, they would not perform correct behaviours. It means that the scope of this learning theory is limited.

**Cognitivism** studies the “black box” of the mind of a learner, in which the person is regarded as an information processor like a computer, and the thought process behind the behaviours is investigated through observing the changes of the learner in behaviour [38] [39]. This learning theory focuses on the exploration of the mental processes of humans, such as memory, thinking, and problem solving. For example, in this theory an internal knowledge and cognitive structure is seen as a schema. Through combining, extending or altering schemas, new information is aggregated

into people's existing cognitive constructions. That is, learning is described as the changes in a person's schema. The theory of cognitivism is very valuable and necessary for understanding how people learn [40]. In the real world, people are not programmed animals that only respond to environmental stimuli. People have the ability to perform inner mental activities and actions directed by the consequences of thinking. Also the changes in the behaviours of the human are observed, which are used as indications of what is happening inside the learner's head. In cognitivism, through observing the learner's environment, new information comes into the mind of the person. Next, the information is processed (e.g. thinking and assembling) based on the current cognitive structure of this people. Finally, certain outcomes will be produced by the learner, such as new knowledge structures and cognitive procedures.

The analysis about the main research of people (e.g. Piaget, Reigeluth, Johnson-Laird, and Weiner) in the theory of cognitivism is listed below:

- Piaget is famous for the stage theory of cognitive development that regards the procedure of aggregating new information into children's old knowledge structures as four different stages: sensorimotor, preoperational, concrete, and formal [41] [42]. Through observing children, Piaget described their processes of making the sense of the world around them. Then, a four-stage model was built to show how the minds of children process the new information that they encountered in certain situations in the same order. The first stage (sensorimotor) indicates that the infants under 2 years old are able to interact with the environments where they are in. In detail, learning is done through getting some information, organizing it, and absorbing or including it into the current cognitive structures of babies (assimilation and accommodation). Then, they can have an initial understanding of themselves and reality, such as how to distinguish themselves from other objects and how things work. In the preoperational stage, children aged 2 to 4 rely on concrete physical situations without the ability of abstract conceptualization. For example, they classify objects by typical and clear features such as which toys can make a sound. The concrete operations stage says that children aged 7 to 11 have the basic capability of abstract thinking and conceptualizing, and building logical structures to interpret their accumulating physical experiences. The last stage is formal operations in which people aged 11 to 15 do not need concrete objects to

make rational judgements. They are capable of deductive and hypothetical reasoning, and have abilities similar to an adult in abstract thinking. Piaget gave a practical approach to represent the procedure of the increase of cognition abilities as well as the related mental models, which suggests that children in different age stages have different capacities and ways of understanding things [43]. The importance of this theory is that it provides a strong basis for properly scheduling the school curriculum, such as the coursework in primary and secondary instruction should be on different degrees of difficulty as children have different understanding capability [44].

- Reigeluth's elaboration theory organizes instruction from simple to complex order and moves from prerequisite learning to learner control [45] [46]. This principle researches the area of the ways of sequencing learner-centred instruction. In detail, learning content should be managed in increasing order of complexity. Furthermore, a meaningful particular context is provided to learners to aggregate their ideas on their learning topics. Moreover, learners view the main concepts of a course and then move to more of a self directed study. The theory discusses an instructional design approach used to describe the cognitive processes from medium to complex degrees [45] [47]. This method can support learners to select and sequence materials by using motivators, analogies, summaries, and synthesis. Generally, the method comprises three major categories: conceptual elaboration sequence, theoretical elaboration sequence, and simplifying conditions sequence [45]. The conceptual elaboration sequence is used in an environment where there are a lot of relevant concepts to be learned, which is regarded as teaching or discovering from broadest, most inclusive, and general concepts to narrower, less inclusive, and more detailed ones. The theoretical elaboration sequence is applied in a situation in which learners have to grasp many related principles. This learning method can be implemented by elaborating both causal and resultant factors or either of them, such as what causes this, what else can cause this, when causes this, what happens, and what else happens. The simplifying conditions sequence is mainly adopted to accomplish a task with moderate or higher complexity. In this sequence, learners start from the simplest version of a task (the whole representation of a task), walk through a set of more complex versions of the task, and finally reach the desired layer of complexity. In this elaboration theory, learners can do instruction sequencing as holistically as possible, which greatly enhances

people's meaning-making ability and their learning motivation, and facilitates the rapid creation of the elaborative prototypes for all kinds of learning objectives in instructional development processes [48].

- Johnson-Laird's mental model theory is a learning mechanism for representing reality in a person's mind, in which mental models are regarded as the basic structure of cognition and are used by people to understand specific phenomena [49] [50]. It can simplify the explanations of complex phenomena and the representations of a phenomenon are usually not accurate. It also can measure the validity of uncertainty to show whether they can be used. This theory studies how people develop the internal mental models of themselves, others, environments, and other objects. Also the possible analogy procedures between the models of one knowledge domain and others are investigated. The method has discussed how mental models help people perform their cognitive processes. The main achievement of this theory is to provide a unified description of deductive and probabilistic reasoning procedures by using mental models [51] [52]. In detail, a person deduces that a conclusion must be true as it can be supported by all of their models of the premises. If the most of a person's models of premises prove an argument, it is likely to be true. If an issue is demonstrated by at least one of a person's models of premises, it may not be true. The major value of the theory is to let instructors master the internal cognitive processes of the mind of students, which can facilitate teachers to complete effective instructional design [52]. Furthermore, learners may establish and manage their own educational procedures in terms of their preferred mental models, which is very helpful for improving their learning motivations.
- Weiner's attribution theory is used to explain the world and to determine the cause of an event or behaviour [53] [54]. Attributions are the explanations about why people do what they do, which are classified over three causal types: locus of control, stability, and controllability. The first kind of attribution consists of two categories: internal (assigning causalities to factors within people) and external (assigning causalities to outside agents) explanations. The second type refers to whether causes change over time or not. The third kind of attribution focuses on the human-controlling causes such as skills and other causes people cannot control such as chance. Generally, an attribution process is made up of three steps: observing behaviours, determining behaviours to be intentional, attributing behaviours to internal or external causes. According to Weiner's

research, the most important components influencing attributions are ability, effort, level of task difficulty, and/or luck. The theory provides a way to explain a variety of people's cognitive procedures based on causalities, which is very useful to influence learners' future behaviours [55] [56].

The major advantages and disadvantages of cognitivism are described as follows [19] [36] [37]:

- The theory can be used to train different learners to complete a task in a consistent way, which can make it very easy for instructors to design instructional processes from the point of standardization. It is very helpful for learners to increase their learning efficiencies, such as the work in a factory is divided into a series of standard pieces in which any worker only needs to have the small capability of performing a simple step. Additionally, in order to measure whether learners master the indicated knowledge or skills, or their mastering degrees, it is very important to ask people to operate their behaviours over the same learning procedures as well as steps. An example of this is that the rule for logging into and out from a computer in a lab is the same for all students who then will be required to execute the same operation to sign in and out.
- It is difficult for the theory to help different learners use different approaches to accomplish their tasks in various situations. In the real world, different learners have different background knowledge and skills, objectives, and learning time (e.g. children and adult). These factors mean that people need a variety of learning processes in practice (sections 2.3. and 2.4.). The learning theory focuses on training people to do a task by the same procedure. This makes it difficult to meet the various requirements of learners.

**Constructivism** is an individualized learning mechanism in which people build their own perspective of the world via personal experiences and knowledge structures [57] [58]. Here, any learner is an information constructor, who actively creates a subjective view of objective reality. It means that new information is subjectively integrated into existing knowledge constructions based on individual experiences and hypotheses. Each person has a different interpretation and construction of knowledge. This theory can be helpful for a person to increase his/her cognitive and research ability through constructing a new knowledge structure over a learner's previous one [59] [60]. An example of this is problem-based learning that is very helpful in training people to improve their abilities in updating or extending their mental

structures. In detail, learners observe an object or event and find a problem. Next people's existing knowledge constructions are used to deal with the information relevant to this problem, such as constructing a solution by using the past knowledge, experiences, and skills. Finally, through solving the issue, some new knowledge, experiences, and skills are obtained by learners, which leads to the improvement of their previous cognitive structures.

The detailed exploration of contributors in constructivism is analyzed as follows:

- Bruner's learning theory (related to the research of Jean Piaget) is a cognitive constructivism principle in which learning is an active procedure and learners interact with the world through investigating and processing objects, questions, and controversies, or performing experiments [61] [62]. This theoretical framework is built on a series of cognitive structures such as schemata and mental models (see the above paragraphs), which mainly helps people to understand and organize their own experiences and knowledge and to construct new cognitive structures by integrating the given information. In order to implement this type of learning, learners should have a high-level predisposition towards learning. Next, new information (e.g. knowledge) should be structured in the ways that people grasp the novel things as easily as possible. In addition, learning resources should be presented to people in the sequences that should enable learners to understand the meaning of resources. Finally, the types and pacing of rewards and punishments should be carefully decided. In this theory, learners draw on their individual past and current experiences and knowledge to discover the facts and relationships in their specific environments and to construct their new mental constructions. This approach is better than a transmissionist model (a teacher transmits information to learners) in promoting students to remember their discovering concepts and knowledge (motivation) [63] [64]. Furthermore, Bruner's theory provides a strong basis for people to develop other learning mechanisms such as guided discovery (section 2.2.6.) and problem-based learning (see the following paragraph).
- Situated learning from Lave and Wenger proposes that learning is a function of an environment including different activities, contexts, and cultures, which builds varieties of communities of practice for learners to acquire certain ideas, knowledge, and skills [65] [66]. This kind of learning contrasts with classroom instruction in which the knowledge involved in learning activities is abstract and

out of context. A community of practice consists of three components: domain, community, and practice. A domain is a shared specific topic of interest (e.g. a group of history teachers in a middle school), in which people should achieve membership. A community is an environment in which members of a domain help each other, share information with each other, and learn from each other through regular interaction in shared activities. A practice describes the activities that members should complete such as developing shared stories, helpful tools, conversations, and ways of dealing with particular problems, and using them together. Through setting the content in the aspects of domain, community, and practice in terms of people's common interests, this theory describes a road of learning based on social interaction, collaboration, and authentic context [67] [68]. As learners move from the periphery of their situated communities to the center, they feel themselves to be very close to the layer of expert, which promote them to become more active and engaged in learning [65] [66].

- Vygotsky's social development theory is a learning approach in which learners obtain knowledge, experiences, and skills via social interaction and collaboration under the guidance of the more knowledgeable other (MKO) in the zone of proximal development (ZPD) [69] [70]. In this theory, social interaction refers to the influences caused by people's behaviours on the social level, which plays a fundamental role in the process of cognitive development. Vygotsky believed that the social learning between people precedes the cognitive development inside a child. The MKO is anyone (e.g. a teacher, an older adult, a younger person, or computers) who has a better understanding or higher learning ability than a learner in a particular task, process, or concept. The ZPD is the learning procedure performed by a student under the MKO direction and collaboration in order to increase the ability of solving the problem independently. Vygotsky's research is mainly in the association between people and the social cultural background in which they interact in shared knowledge and experiences. Generally, people use tools (e.g. speech and writing) from a culture to interact with each other in their social environments, such as learners use these tools to exchange learning experiences. In summary, Vygotsky studied a method to achieve the internalization of the tools in people's minds in order to improve the thinking skills of learners. Compared with transmissionist models, this approach promotes students in playing an active role by using rich learning contexts [71] [72]. Furthermore, according to the theory, instructors should collaborate with

students, which changes the roles of teachers and learners. This learning approach is very helpful for students to facilitate the construction of their knowledge structures in cognitive development [69] [72].

- Problem-based learning (PBL) is a pedagogical method, in which learners are encouraged to study and discover meaningful solutions to contextualized, messy, and real-world problems by themselves [73] [74]. Here, learning is driven by challenging problems and is performed in all kinds of specific contexts of problems and cases. Learners are asked to do self-directed and active studying and problems solving in collaborative groups. Staff play the role of guiding learning procedures and building an environment that can encourage students to do inquiry. In order to effectively operate problem-based learning, instructors should carefully measure the current knowledge level of students. This can help learners to know the important points for their learning, especially in the fields which they have little experience. Another aspect that needs to be considered is that the implementation of this method is very challenging for staff because it asks teachers to do a lot of planning and hard work and to relinquish control of students' learning processes (e.g. guiding learners to do heuristic thinking rather than handing them solutions). However, this theory provides an instructional strategy for students to apply their existing knowledge, skills and experiences to new situations [75]. The method can develop learners' critical thinking and creative abilities and increase their problem-solving skills. In addition, it can greatly enhance the learning motivation of students [76].

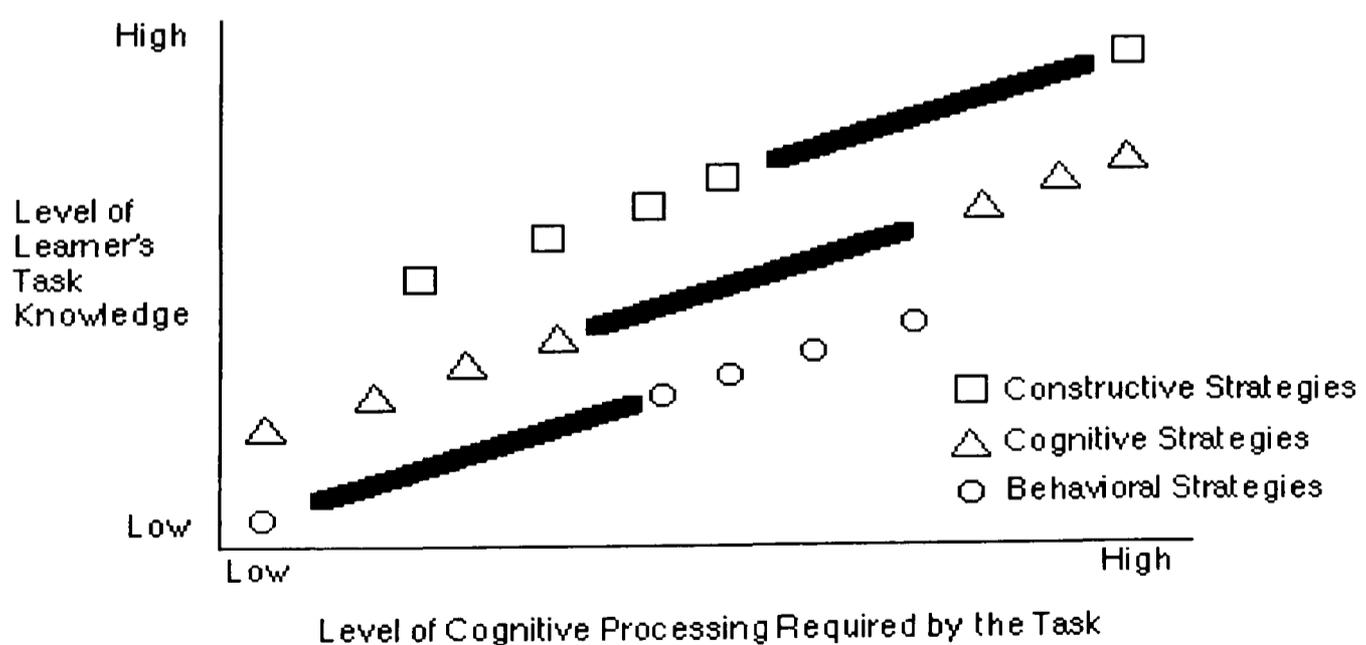
The strengths and restrictions of constructivism are described as follows [19] [36] [37] [77]:

- This theory provides a strong basis for learners to interpret complex realities based on their own perceptions and specific environmental learning features. Compared with behaviourism and cognitivism, this theory can make people better able to deal with all kinds of factors that are associated with human and actual learning environments. An example of this is that through using the method of problem-based learning, it is more easy and efficient for learners to apply their existing knowledge and skills to a novel situation.
- This theory cannot match with the situations where conformity is essential and divergent thinking and behaviours may cause problems. For instance, if every person decided to drive their cars disregarding highway rules, chaos would result.

Furthermore, although there could be some individual and convenient paths for people to pay tax, a common road was still designed and performed. So it is desirable to provide a compulsory and confirmed learning procedure for human to grasp certain knowledge and skills and regularize their personalized actions in terms of the same principle.

### 2.1.3. Learning Theories and Instructional Design

According to the research of Ertmer and Newby [19], the educational strategies developed based on different learning theories overlap in designing learning processes as the same strategy can be used to meet a set of different requirements of users in instruction. Furthermore, the strategies established over a learning theory are distributed as a series of different points along a continuum consisting of the foci of this theory. So each strategy can be used to match with only part of the emphasis of a pedagogic theory. In addition, the levels that cognitive processing and learners' task knowledge require always differ from each other for the basic learning theories. It means that different strategies from different basic theories should be used at different layers of education. For instance, learning methods associated with constructivism are more suitable than others for accomplishing the instructional tasks of high difficulty. All of these three features are illustrated in figure 2.1 [19]. In summary, the instruction designer is able to draw from a large number of strategies built on the basic learning theories and to meet a variety of learning situations. This allows designers to make the best use of all available practical applications of the different learning theories.



Comparison of the associated instructional strategies of the behavioral, cognitive, and constructivist viewpoints based on the learner's level of task knowledge and the level of cognitive processing required by the task.

Figure 2.1 Learning Theories and Instructional Design Taken from Ertmer and Newby [19]

In detail, the relationships between the theories and instructional design are described as follows [19]:

- Behaviourism supports a low layer of processing of behavioural tasks in education, such as basic paired associations and discriminations. Paired-associate learning requires a subject to study pairs of items (e.g. stimuli and responses) by building associations between them. An example of this is that a person responds to a stimulus (e.g. the view of a person's face) with a response (e.g. a name). Discrimination refers to when the same stimulus leads to different responses. For example, different learners may get different results in remembering a formula although a teacher tells them in a classroom. Furthermore, behaviourism focuses on obtaining achievements through building the association between stimuli and responses and reinforcing this kind of relationship. For instance, command teaching and individualized instruction (e.g. Keller Plan [78]) allow instructors to train students by using the mechanism of stimulus and response. Here, based on operant conditioning, learners are required to answer a question and then feedback on the correctness of the response is sent to them. In the Keller Plan, also called the Personalized System of Instruction (PSI), teachers adopt the personalized approaches in instruction [78], such as individually paced method (sections 2.3.2. and 2.4.), mastery learning (comprising pretest, teach, test the result, adapt procedure, and teach and test again) [79], content chunking (learning materials are broken down into small units with fixed orders), and statistical tracking (comparing students' individual learning speeds against their overall learning speed and then taking the appropriate ways to help students who have troubles on a certain unit). In addition, in behaviourism instruction, learners can also be motivated by personal and social factors [80].
- Compared with behaviourism, cognitivism can implement the higher layer of processing of instructional tasks through the internal mental processes of the mind. The instructional design models based on cognitive learning theory focus on how to promote the functionality of the parts of "task analysis" and "learner analysis", and how they could be used to improve the effectiveness of learning [81]. These models consist of a set of components such as knowledge representation, information storage and retrieval, and the aggregation of new knowledge with previous information. By using cognitivism strategy, cognitive tasks would be analyzed and broken down into small steps. Next, this

information is used to develop complex educational procedures based on previous simple processes. An example of practical instruction over cognitivism is LOGO [78] in which young children learn simple knowledge by using turtles under the method of discovery and exploration learning (section 2.2.5.).

- Compared with behaviourism and cognitivism, constructivism can support the higher level of cognitive processing required by instructional tasks, such as heuristic problem solving, personal selection, and monitoring of cognitive strategies. Heuristic problem solving [82] supports learners to build their individualized rules or procedures on the existing ones. Next, under these rules or processes, satisfactory solutions are created for specific problems. The main restriction of heuristic problem solving is that it is very difficult to master heuristic technique as the methods are very problem specific. The value of constructivism theory is that educational environments are established to characterize varieties of constructivist approaches, which largely facilitates the construction of users' personalized learning processes in order to meet their particular requirements [83] [84]. Furthermore, this theory is very helpful in developing other instructional methods, such as reciprocal teaching style (section 2.2.2.) can be supported by the joint construction of users' ideas in group discussion and teacher guided construction of knowledge refers to subjectively integrating the selected learning materials to arrive at particular instructional goals [85] [86].

As discussed above, the basic learning theories have been derived from the high-level theoretical features reflected by a variety of actual instructional processes. As these theories are very abstract, so a set of educational styles are produced through building the bridges to connect the theories and practical learning procedures. These patterns can apply the advantages of the theories in the real world of instruction. An example of this is that guided discovery learning (section 2.2.6.) focuses on reinforcing students' continuous mental thinking until they achieve the learning aims (Cognitivism). Also this manner supports learners to get the correct result by constantly building the new layer of understanding and knowledge over old ones (Constructivism). Through designing, performing, and controlling learning processes under the direction of instructional patterns, instructors and students can implement their specific educational demands as far as possible. That is, users can consider a variety of approaches and then establish the appropriate ones to meet their

personalized requirements such as objectives, age and group of students, and general or specialized instructional processes. The detailed information is discussed in the following sections of this chapter.

## **2.2. Instructional Approaches**

Based on the learning theories analyzed above, historically a series of teaching and learning styles were produced to direct the completion of all kinds of instructional tasks. These methods refer to a set of educational mechanisms for students to acquire knowledge, experience, and skills, which provide the ability to support a variety of personal and adaptive interactions between staff and students [87] [88] [89]. In order to benefit learners to achieve their learning aims, it is essential to support different educational styles to meet students' personalized needs in education [90]. That is, students are characterized by using different styles. There are a lot of instructional patterns in the pedagogy area. It is difficult to list every one in this thesis. Here we present ten examples of these approaches: command, reciprocal, self-evaluation, guidance and counselling, self pace (e.g. discovery learning), guided discovery, deep learning, surface learning, serialist learning, and holistic learning. The detailed representation of them is shown in the following sections.

### **2.2.1. Command Teaching**

The command teaching style [91] refers to when teachers control all the things in the procedures of instruction. Teachers make decisions about learning time and date, learning units, learning sequences, learning places, assessment methods and standards of learning results, new learning strategies based on the evaluations, and so on.

The advantages and disadvantages of this method can be described as follows [92]:

- One of the advantages is that staff can control students' learning processes under their teaching experiences. Also teachers can provide all the necessary learning materials to students to be used to get the expected outcomes. In addition, staff can strictly manage students' learning procedures, such as controlling the learning content as young children may avoid the items (e.g. mathematics) that were difficult for them to understand [93].
- One of the disadvantages is that students have little freedom to think about their personalized learning units and processes. Moreover, the creativity of students has not been encouraged, as all of the elements in learning are determined by

teachers [94]. This style is staff-oriented and limits students to performing a restricted number of objects, which hinders the learning initiatives of learners.

### **2.2.2. Reciprocal**

The reciprocal work [95] is an educational method which can support students to learn and discuss questions in groups with different subjects. One student can get helpful feedback about his or her learning units, processes, and results from other students in the same group [96].

The advantages and disadvantages of this pattern can be described as follows:

- One of the advantages is that it is easy for students to communicate with each other to get the useful information about the learning questions pre-designed by staff and/or learners [97]. Furthermore, through monitoring the discussion content in groups, teachers can grasp the problems occurred in learning and deal with these issues as early as possible. This is very helpful for achieving the instructional goals.
- One of the disadvantages is that learners often need to spend a lot of time to obtain suitable answers to their questions. Students do not have the right to select their individual learning elements to meet their demands as they need to work in a common way, such as the decisions of aims, content, tools, and steps to do this discussion [98]. It is not helpful to improve students' learning interests.

### **2.2.3. Self-Evaluation**

In self-evaluation instructional method [99], learners are allowed to make the observational assessment of their personality preferences in completing their learning tasks. Then the required learning units and teaching strategies are offered by teachers to students to meet the needs of these preferences.

The advantages and disadvantages of this approach can be described as follows [100]:

- One of the advantages is that students may select learning content according to their interests. Also learners may assess the results by themselves [101]. If the results do not match with the aims, learners can choose other resources based on the analysis of these results and try again. If students arrive at their goals, they may post their work to the teacher to get a final evaluation. Thus, this method is useful to improve the independently learning abilities of tutee.
- One of the disadvantages of this approach is that most students do not grasp the standards of assessment to their learning results, as they do not have enough

skills, experience, and background knowledge in selecting and using appropriate evaluation methods [102]. Additionally, learners always focus on what they are interested in without thinking whether it is valuable or not [103]. This specially applies to the difficult courses (e.g. mathematics, physics and engineering), which learners (such as young children) would like to skip to do some other subjects that they perceive to be easier. So the knowledge range of students will become very limited, which is not beneficial for the learners.

#### **2.2.4. Guidance and Counselling**

The guidance and counselling method [104] is used to enable students to make proper learning and acquire the right skills in terms of their personalized requirements for a career. The aim of this pattern is to promote the personal/social, educational, and career development of people. This method is valuable for learners from secondary to lifelong learning [105]. In this style, teachers determine learning resources in terms of students' personal aims. Next learners design their individualized learning programmes, such as setting the personal schedule of learning and the sequences of the selected learning units. Then students undertake learning under the management of teachers. That is, teachers have the rights to control the processes in order to make learners achieve their required objectives as soon as possible.

The advantages and disadvantages of this manner can be described as follows:

- One of the advantages is that teachers with a lot of experience in a certain area can offer appropriate learning materials to learners according to their personalized topics [106]. Also staff may ask learners to learn some demanded, difficult, and uninterested content that is valuable for them to achieve their aims in a career. Furthermore, students could make their individual time plan for performing tasks, which can provide the freedom for them to do the learning in terms of their different circumstances. They can adaptively increase the learning time on their weaker areas and reduce the time on better areas.
- One of the disadvantages is that learners may not have the ability to design suitable learning plans because they lack of the relevant experience [107]. For example, a student planned to spend three weeks on a topic. During learning, this student may find he or she needed more time to learn. It means that it was difficult for them to obtain the knowledge and/or skills required by employers before the deadline. Furthermore, learners do not have the rights to select

learning units according to their personal interests. For instance, students may not get their preferred books or other documents, which is not helpful to encourage the positive learning attitudes.

### **2.2.5. Self Pace**

The self pace style [108] refers to when learners take full responsibility for their learning without the conventional interaction with teachers. For example, students determine their individual learning schedule, learning materials, and evaluation standards of results. That is, learners control their learning procedures by themselves without the supervision of staff.

A good embodiment of this instructional pattern is discovery learning [109] that is a personal, internal, constructivist-style learning method (section 2.1.2.) without teachers. This method implements the main values of self pace manner, which enables students to make big progress in the abilities of understanding knowledge. The method is always used in problem solving situations, and the needed information and evidence is usually presented to learners in a pre-designed proposal. Generally discovery learning consists of three steps [110]: motivation, discovery, and presentation. Motivation is the guidance principle of the whole learning procedure. Next students call on their prior experience and knowledge to discover the meaning of the content that they are learning. Finally, the new information or skills are shown to learners. One of advantage of using this method is that students can think and work more creatively than before [111]. Also this method encourages learners to develop problem-solving strategies in the unknown or unfamiliar areas.

One of the well-known computer-based applications of discovery learning is LOGO [112] that refers to a computer language used to reflect and promote Piagetian learning (section 2.1.2.). LOGO is a primary example of constructive application based on a set of small but complete subset of reality called microworlds [113]. In a microworld, one student can learn a particular knowledge domain by personal discovery and exploration. In general, LOGO is often used to teach very young children by providing a turtle that is a robotic creature moved around on the floor [114]. A turtle presents some simple knowledge in an interested format such as moving forward 10 turtle steps in a straight line by using computer.

In sum, the advantages and disadvantages of self pace manner can be described as follows:

- One of the advantages of this method is that learners can plan and manage their learning towards their personalized objectives [115], such as selecting the particular learning content, designing the learning steps according to their own situation, and building their personal timetable. This is very helpful for students to improve their learning interests. In addition, learners can get a lot of experiences in how to acquire the required knowledge and skills by themselves. It is very useful in cultivating the skill of independent problem solving in students.
- One of the disadvantages of this style is that staff cannot provide their abundant teaching experience to students, which should be very useful for students to make correct decisions [116]. Moreover, this method asks learners to have as deep an understanding as possible of their courses, which could be very difficult for students. Learners may not have enough capacity to plan the learning procedures by themselves, which makes it difficult to assure students manage their learning correctly and efficiently.

#### **2.2.6. Guided Discovery**

The guided discovery pedagogy manner [117] is an interactive educational mechanism, in which teachers design some movements indicating particular aims and challenges and learners go to find the solutions under the guidance of staff. In this style, students are encouraged to express various models of learning, reasoning processes, and knowledge domains to accomplish their individualized tasks. Also the models of dialog and teaching processes are built by teachers to efficiently manage the learning procedures of learners.

The ascendancy and restrictions of this method can be represented as follows [118]:

- One of the advantages of this style is that students' creativity can be encouraged, which is helpful for learners to study personal courses that they are interested in. In addition, this style can enhance students' self-concept ability that is used to organize and interpret their inner world of personal existence. A positive self-concept is very helpful for learners to build a good attitude in learning. Furthermore, staff may rapidly master the learning abilities of students and divide them into a few groups with the similar layers, which is helpful to improve the efficiencies of instruction [119].
- One of the disadvantages of this method is that learners always take a long time to achieve the instructional objectives [120]. Also teachers need more time to

prepare the personalized learning processes and units. More feedback is also needed to be delivered to students to complete their educational aims.

### **2.2.7. Deep Learning**

Deep learning focuses on a high level of understanding of a certain topic through critical analysis of new facts and ideas and linking them to the concepts and principles in the existing cognitive structure of a learner [121]. Through integrating what they are learning into their already obtained knowledge and personal experience, people are intrinsically motivated to improve their learning abilities [122]. This is very helpful for problem solving in unfamiliar contexts.

The advantages and disadvantages of this pattern can be described as follows [123] [124]:

- The approach can facilitate learners to understand the intention of an idea, such as what an author's arguments signify. Furthermore, the method can build the relations and distinctions between new ideas and previous knowledge and experience. That is, the content, including what a person is learning and has already mastered, is structured and organized around the emphasis of learning. Deep learning is a subject-focused approach for learners to construct their view of reality.
- The main disadvantage of this method is that it is difficult for students to get the high cognitive thinking skills about how to develop a deep understanding in a certain knowledge area. Learners should have the capacity to analyze a set of new ideas and integrate them into the existing knowledge framework through building the logical relationship between the ideas and the framework in order to improve their cognitive construction. However, in the real world, learners may become very unconfident or give up, especially when they spend a lot of time on a problem and still cannot solve it. Furthermore, students are not interested in completing a set of hard work in order to arrive at their learning aims. Both of them block learners in developing their thinking abilities.

### **2.2.8. Surface Learning**

Surface learning refers to an instructional pattern based on accepting new facts and ideas uncritically and memorizing them as isolated and unlinked items [125]. This approach focuses on the discrete elements marked by task requirements, such as the memorisation of the information used in a test and the related assessment procedure. Surface learning suggests a task-focused approach to learning and has more extrinsic

value than deep learning, such as the value from the grade obtained through a specific instance of learning [126].

The advantages and disadvantages of this method can be shown as follows [127] [128]:

- The method can motivate students to study the knowledge that they may not be interested in, which is helpful for people to build and improve their cognitive structures. For instance, children in a primary school are stimulated to learn a set of different kinds of courses (e.g. mathematics and English) by grades and exams. These curricula may be very boring to pupils, but they are fundamental for people in constructing their own knowledge and cognitive frameworks.
- The major restriction of this style is that the superficial understanding of ideas and facts (rote learning) plays the main role in children's learning, which misses the promotion of the mastering and long-term retention of knowledge and information. An example of this is that learners always limit their learning ranges and thinking ranges according to the demands of examinations. In addition, the technique of surface learning focuses on the memory of the knowledge (e.g. all kinds of mathematics formulae) not the association of concepts and facts. It means that this manner cannot encourage people to abstract the principles from the present evidence and integrate the new things into their old cognitive architecture.

### **2.2.9. Serialist Learning**

The serialist approach is a learning technique in which people learn a subject in an unfamiliar field from the bottom to the top step by step [129]. It is a method used to move from the known knowledge, skills, and experiences to the unknown field through building varieties of simple connections between the existing information and new knowledge [130].

The major advantages and disadvantages of this approach are represented as follows [131] [132]:

- Serialist learners always acquire new knowledge, skills, and experiences in a sequential fashion. Also people complete the sequenced chunks with set learning procedures and methods. Both of them can provide a general road for students with different learning abilities to achieve a task. Furthermore, this style supports students to do their learning from the surface to the depth, which

facilitates people to build up the logic association between the items in their knowledge structure.

- Serialists may lose sight of the broad picture of their learning as they focus on the concrete content in each learning step and the linear relation between steps. Learners do not study the theoretical meaning of the content that they are learning, which makes it difficult for them to construct the high-level view of a topic.

### **2.2.10. Holistic Learning**

Holistic learners prefer to begin with an overall framework of a subject and then explore the details within it until they fill in the whole [133] [134]. Through building the models of a topic, people have a good understanding about the components in this area and the interaction among them. Next from the top to the bottom, learners produce a set of chunks of understanding to solve problems. Finally, a new knowledge construct is formed in a hierarchic manner.

The advantages and disadvantages of this style can be described as follows [135] [136]:

- Holistic learning can provide the convenience for people to create the webs, constructs, and models of information by accomplishing an underlying exploration of a subject. This makes it easy for people to understand the highly conceptual information including its underlying framework.
- A disadvantage of this method is that it is difficult for learners to build a whole and high-level view of a topic. For example, students may not find all of the building blocks of a construct, or build the correct connections among these elements. This leads students to become more and more unconfident in achieving their learning goals. It is adverse to cultivate the learning enthusiasm of students.

According to the above discussion, there are a set of instructional styles used by learners and staff to efficiently and effectively discover and manipulate what they learn [137]. So it is essential that virtual learning environments should provide the functions to support these patterns.

### **2.3. Individualized Creation of Educational Processes**

An instructional process is a procedure for students to obtain knowledge, experiences, and skills [138]. Here we summarize the main demands of pedagogy styles from the

point of the designing and authoring of learning processes, which could be a key condition to support these patterns. Generally a procedure consists of a set of learning activities, such as presentation, developing an understanding of concepts, reinforcement, and exercising [139]. Also the behaviours of learners and teachers in processes are specified, personalized, and changeable [140]. As different users may have different goals in education, the possible behaviours of them in a given situation could be very different [141]. Furthermore, different students may have different background knowledge, different learning results, and different schedules of learning [142]. So there are a lot of different instructional procedures used by learners and staff in the real world [143]. When the needs of people in education are similar, a general procedure will be designed for them (e.g. children in primary schools). If people have different demands in instruction, different processes will be created for them (e.g. students in international language schools). Thus, instructional processes could be classified into two types: common and individual educational processes.

### **2.3.1. Common Educational Process**

In this thesis, a common instructional process is a type of educational method that focuses on the general requirements of students [144]. This method could be very suitable for primary and secondary schools, in which the instruction is mainly responsible for the common needs of learners. Also the method could be used to train people with little knowledge or skills in the same field. In addition, students and teachers may cooperatively decide the common learning resources. As producing and controlling generic instructional procedures rather than caring about users' personalized demands, learning processes can be designed and managed easily.

The advantages and disadvantages of common process could be described as follows:

- One of the advantages of this method is that it could be very useful for staff to teach a lot of learners with the same demands at the same time [145]. For example, children in primary schools lack the basic knowledge in a set of fields such as language and mathematics, which shows that they have the same requirements in learning. Here it is a better way to teach students together rather than separately, because they need the same basic things to construct their fundamental cognitive and knowledge framework. This framework is the basis for their future learning in their selecting subjects, such as computer science in higher education. Also the number of teachers is limited and cannot support one-to-one teaching. Even if there were enough instructors, it was still not a valuable

and efficient way to teach children one by one as each teacher would repeat the same instructional content and behaviours for several times. So the method of common educational process should be considered to support staff to get students together and teach them the same knowledge in the same stage of time, which can save a lot of time and money.

- The main problem of this method is that it offers no freedom to learners [146]. Students have to study the content selected by teachers, even if these materials do not match their demands. Also the processes are designed for general needs, and learners can not aggregate the content in terms of their personalized requirements. That is, this type of learning process focuses on the commonness of students and omits their individuality [147]. So this approach cannot provide the appropriate convenience for learners and staff to adapt varieties of practical demands [148].

### **2.3.2. Individual Educational Process**

In this research, an individual teaching and learning process is a kind of instructional approach that focuses on all kinds of personal needs of students [149]. This method is suitable for learners who know what knowledge and/or skills they want to obtain [150]. Also people with disabilities and/or learning difficulties are interested in personalized educational procedures [151]. Through adding various individualized requirements (e.g. the interested content of students and the teaching experience of teachers) into the processes, learners and staff can have much more freedom in completing their specific instruction.

The advantages and disadvantages of individual learning process could be described as follows:

- The main advantage of this method is that it could provide the flexibility for teachers and students to establish their personalized educational processes [149]. It is designed mainly for the individuality of learners and omits their commonness. Students may import their preferred learning units into the processes. As different learners have different learning abilities, the method could provide learning units at an appropriate level of difficulty. Furthermore, the instruction schedules could be individualized to meet varieties of requirements of learners and teachers. Moreover, students (e.g. in an international language school) may hope to design the relationships among the indicated learning units in terms of their personalized needs [152] [153]. It

means that learners can directly attend exams without completing the learning content in front of these tests [154]. If they do not pass the exams, they may return to learn this content. Finally, the various demands of employers in knowledge, experiences, and skills could be added into individualized educational processes. Then, students may select their interesting processes and perform them, which could be helpful when students apply for jobs.

- The main problem of the method is that it could be very difficult to implement [155]. Every learner may have a number of particular requirements, such as one student may use different ways to learn different modules or courses. Furthermore, the non-electronic resources (e.g. books, journals, and classrooms) in an institution could be limited, which makes it difficult to meet the individual needs of learners [156]. For example, there could be a lot of students to borrow the same book. In addition, the number of staff is much less than the number of students. The workloads to support all kinds of personalized learning processes could be too large for teachers in the real world. So existing educational organizations only can provide the restricted support for individuals' processes [157].

As varieties of instructional processes are used by users, so it is very important for virtual learning environments to provide adequately broad avenues for education. It could be very helpful to support users to build their preferred styles.

#### **2.4. Individualized Control of Educational Processes**

The individualized control of instruction processes refers to the flexible management of educational procedures and units during the execution of these processes [158]. This section discusses the main requirements of pedagogic styles from the point of the personalized coordination of processes during running in terms of the needs of users [159], which could be another key aspect to implement these styles. The aim of this control is to provide the flexibility to users as far as possible [160].

The main function of this control is to support the demands of learners and teachers emerging during performing instruction [161] [162] [163]. For instance, learner A builds a learning process that consists of three exams related to the certificates at the three levels in language education. The design of procedure by learner A is such that the second exam will be taken first. Next according to the result, student A will go to attend the first exam if he or she fails in this test. Or learner A will start to learn a set

of lectures and finally to enter the third exam if he or she passes the second one. During this procedure, student A obtained an excellent result in the second test, so the learner hopes to try the third exam directly. If the student achieves this test, he or she will get the preferred certificate. Then learner A may start higher education as this third level certificate has met the demands of some universities. A lot of time and money will be saved as student A does not need to perform the pre-designed learning units. Furthermore, if this learner does not pass the third exam, he or she still can do these lectures under the planned process and attend the final test again. It is shown that student A has some new ideas during execution, which could bring the benefits discussed above to him or her. It means that the previous instructional procedure should be flexibly coordinated in terms of the actual demands of users produced during the running of e-learning Web services and applications.

In summary, users need to control their instructional processes during execution in terms of their individual requirements. It means that virtual learning environments should support users to flexibly manage their educational procedures (e.g. building new sequences between learning units) during performing these processes [164].

This chapter analyzed basic learning theories, a set of educational styles, and individualized creation and control of instructional processes. Next, the relevant systems, approaches, and technologies will be discussed and the technical problems are to be represented.

## ***Chapter 3 Computers and Education***

This chapter analyzes the technical problems in the area of e-learning based on the research of computing technologies. It comprises six sections. The first section introduces the basic knowledge of e-learning. The second section discusses existing open source e-learning tools and commercial software. In the third section, the knowledge of Semantic Web and ontology are taken a scientific view. The fourth section focuses on the knowledge of a set of standards relevant to this research. The fifth section presents the three typical scenarios of existing virtual learning environments. The final section investigates the technical issues in the research under discussion.

### **3.1. Introduction to E-Learning**

In this research, an e-learning system also called a virtual learning environment or a Web-based course-support system [165] can be defined as the following:

“A comprehensive software package that supports courses that depend on the WWW for some combination of delivery, testing, simulation, discussion, or other significant aspect.” [166]

In general, e-learning science is the implementation of the science of instruction on the Web [167]. Through using computer technologies, a lot of e-learning systems and applications were developed [168]. These software packages can support staff and students to get various educational resources to complete their special Web-based learning processes [169]. Both of these systems are put in the environments of various subjects, different learning levels, different instructional content, and all kinds of learning objectives [170]. Also these e-learning systems facilitate users to deliver particular learning units among systems or users, which provides the ability for systems or users to interact with each other. In summary, virtual learning environments aim to develop functions to solve varieties of problems in the area of e-learning science, such as simulating a set of educational styles on the Internet, creating individualized instructional processes, and controlling these procedures during execution in terms of new requirements of learners and educators (Chapter 2). It means that the features of learning theories such as behaviourism, cognitivism, and constructivism (Chapter 2) would be implemented as far as possible on the Web. This is an essential basis for people to achieve high-quality results from Web-based education, because they can design and manage their practical instructional procedures under the guidance of learning theories.

Here, the Open University (OU) in the UK [171] is regarded as an example to present the development of e-learning techniques and the achievements in Web-based instruction. Through successfully developing and applying a series of e-learning technologies over several years, the OU has become famous for providing Web-based curricula for large numbers of international and domestic learners [172]. In the 1960s, the UK decided to build a “College of the Air” that was later to become the Open University [171]. In the beginning the OU, with the help from the British Broadcasting Corporation, provided degree studies by using TV and Radio. Next, computer-based communication was used more and more widely in distance delivery of learning and teaching programmes. For instance, the OU developed the method of

flexible credit accumulation scheme in which students can devise particular programmes on computers to meet their personal requirements such as individual learning schedules and materials, and return learning results to teachers for evaluation [172]. Then, with the further development of electronic techniques, the e-learning network in the OU cannot only provide one-way communication through television and radio media, but also the ability to implement interaction between learners and instructors via the Internet. Now, the OU has around 150,000 undergraduate students and more than 30,000 postgraduate students. Nearly 10,000 disabled students are studying at the OU. In summary, this university has been a successful sample in providing education on the Internet.

So far, there are a number of virtual learning environments that have already been established and many of them are used in educational enterprises such as universities [173]. The functions provided by these systems can be summarized as follows:

First, existing virtual learning environments can facilitate users to complete instructional procedures on the Web, which could be time-independent, place-independent, and course-independent. For example, Teknical Virtual Campus [174] and LON-CAPA [175] offer the functions of discussion forum, real-time chat, work offline/synchronize, course templates, and searching within course. As a lot of books, journals, and other information are transferred into electronic formats, so users can obtain whatever learning resources they want through communicating with other systems or applications on the Internet.

Second, existing virtual learning environments can facilitate users to author concrete learning units, and upload and deploy them on the Web. For instance, AudioGraph [176] is a multimedia authoring tool for devising web presentations for eLearning by using a set of media elements (e.g. vector graphics, pen annotation, and images). In the Learnwise [177] e-learning system, staff can create fill-in-the-blank, image map, multiple choice, multiple answer, scored true/false, ordering, feedback messages, and matching questions consisting of images, video, and other media files. Also the system allows staff to configure dates and times of tests, which is used to control when students can access tests.

Third, existing virtual learning environments can facilitate users to create concrete learning processes, and upload and distribute them on the Web. For example,

Microsoft Class Server [178] supports the combination of the indicated learning materials and delivers lessons and assessments to students on the Web. Quia Web [179] is a free online authoring environment, which offers some easy-to-use tools and templates for staff to create online learning processes with the selected learning units in a linear sequence. In addition, the system has already predefined more than 400,000 online quizzes, lectures, presentations, tests, science games, homework, and schedules for hundreds of subject areas in 15 languages (e.g. English and Chinese).

Furthermore, existing virtual learning environments can facilitate users to communicate with each other when they perform instructional processes on the Web. For instance, FirstClass [180] is a conferencing and email system, which uses conference folders, student notice board, and email to support users' communication. WebCT [181] can provide a set of tools (e.g. discussion forums, file exchange, internal email, online journal/notes, real-time chat, and whiteboard) to facilitate the communications among staff and students, such as attaching, combining, and submitting information including images and annotations during their communications.

Finally, existing virtual learning environments can support users to share and reuse learning units deployed on the Web. For example, Blackboard [182] used in the University of Hull supports a lot of students to share and reuse courses and modules in a virtual learning environment. SharePoint [183] provides the document libraries for users to store, share, and reuse learning units. All of these units are described by staff in the repositories based on standards, and can be used in information-specific discussions in self-defining user groups [184]. Learning Manager Enterprise Edition [185] and Desire2Learn [186] contain the central content repositories, where teachers define and store learning units as private or publicly accessible for specific students. Also these systems facilitate teachers to build links to the learning units, which can automatically present the changes made to the linked learning units to staff.

With the development and application of more advanced approaches and techniques, the functions of e-learning software will become more and more powerful [187] [188]. This ensures the individualized requirements of learners and teachers are met as far as possible. Thus, in the future, the market of e-learning applications has good prospects [189].

### **3.2. Open Source Virtual Learning Environments**

In General, there are four widely-used open source licenses [190]: GNU GPL, GNU LGPL, BSD, and MIT. The GNU General Public License (GNU GPL) guarantees the freedom for users to share and modify free software, which applies to most of free software. Also this license makes software to be free for all its users. Compared with the GNU GPL license, the GNU LGPL (GNU Lesser General Public License) with the same features is mainly for library applications. The main difference between the BSD license and the MIT license is that the former allows the author to hold all the rights of the product and the latter does not. Furthermore, the MIT license not the BSD license supports the redistribution of the modified version of the software. The main advantages of open source software are that a user can use the software for free; download source codes and software specifications from some websites; get other users' practical experience of using the software; and change source codes according to his/her requirements. All of these features facilitate the investigation of the usability issues of open source systems.

So far, there are a number of open source virtual learning environments under the GNU GPL license, such as Claroline [191], ClassWeb [192], Eledge [193], Internet Classroom Assistant [194], and Manhattan Virtual Classroom [195]. These e-learning systems have been developed for reducing the development difficulties of learning units and improving the management of instructional processes on the Web. For example, in Claroline the quiz generator, suggestion list, email service, and telephone conversation system are used to create course websites in a few hours without any technical training or special assistance. Many of these systems are implemented using open source development tools or free tools. For instance, Claroline is built with PHP [196], SQL [197], and HTML [198]. Also the Manhattan Virtual Classroom is programmed in C based on Linux, and the Internet Classroom Assistant is developed with HTML.

#### **3.2.1. Basic Definitions**

In the thesis, e-learning systems, also called virtual learning environments, are computer-based systems, which can access a wide range of learning resources. Such systems can implement the “any time/any place” learning mode, which is not only an efficient mechanism for the management of learning materials, but also a powerful means of authoring learning units [199].

Generally, each virtual learning environment contains a few building blocks such as a learning process management system, and/or a learning content management system. A learning process management system, also called Course Management System (CMS), is responsible for authoring and controlling particular learning processes and sometimes the communication with other systems or applications on the Web. A learning process management system can provide an instructor and/or a learner with a way to create, deliver, and manage learning tasks and procedures in terms of users' requirements [200]. Also this system can support teachers to monitor students' participation and assess students' learning results. Furthermore, the system should provide the ability for learners to manage their own learning processes by using interactive facilities such as email, group discussion, video and audio conferencing, and/or other tools. Finally, this kind of software should support the tasks performed by administrators, evaluators, and authors, such as user management, credit identification, and the publication of learning units. For example, LAMS [201] can facilitate teachers to build learning processes including some learning units selected from a limited range, and to increase the abilities of users' management of learning procedures such as tracking and stopping them. In sum, a learning process management system focuses on the designing and managing of special educational processes.

A learning content management system mainly provides the ability for authors to facilitate the authoring of learning units in terms of the particular needs of learners and staff. Also this type of system can support authors to manage learning units in distributed databases on the Internet. An example of this is RELOAD [202] that makes it easily and quickly for authors to use the interested learning materials to build their personalized learning units. Also RELOAD is established based on metadata standards (section 3.5.), so users can define the semantic information of learning units, such as their titles, descriptions, and version numbers. Furthermore, RELOAD improves the accessibility and reusability of learning units in different virtual learning environments that support the technology of Web browser.

### **3.2.2. Open Source Learning Process Management Systems**

In this section, we present three learning process management systems. The same and different features of them can be described as follows:

Knowledge Environment for Web-based Learning (KEWL) is an open source online learning process management system from the University of the Western Cape (UWC) [203]. The latest version is KEWL which started three years ago by UWC Professor Derek Keats and runs on Windows XP. As some other open source learning process management systems such as ILIAS [204] and Interact [205], KEWL is under the GNU General Public License and can provide the ability to manage learning materials. All of these systems provide the ability to store useful information, such as last visited courses, test, and glossary in local computers. These systems can also provide some tools for users to manage their accounts, such as automatically parsed glossary, search engine for content, readings list, and bookmarks. Furthermore, they provide an integrated authoring environment for users to create courses even without any HTML knowledge. Finally, they can support a number of system languages, such as Chinese, English, French, German, and Russian through central language databases.

There are also some different features among these systems, which can be discussed as follows:

- The key advantage of KEWL is that this system provides offline content and online content in different colours to users, so they know what is available locally and what requires an Internet connection.
- ILIAS is being developed by the University of Cologne in Germany. It is programmed in PHP using a MySQL database and runs on Linux or SunOS/Solaris. One of the different features [206] is that ILIAS provides context-sensitive help system for learners and authors to search, identify, use, and create learning materials. Another difference is that ILIAS can support metadata technology used to describe learning units, which can facilitate authors to create and maintain these content and users to use them.
- Interact [207] is an e-learning tool based on IMS standard and was built by the Christchurch College of Education in New Zealand. In comparison with the above two systems, one difference is that Interact offers the ability for students to add and manage their own learning materials to their personal group areas. Also teachers only need to update the learning materials in one place although these materials could be in many course sites. Furthermore, students and staff do not need to check every forum for new posts, because they can enter all new forum postings from one central place.

### **3.2.3. Open Source Learning Content Management Systems**

This section discusses the main features of three learning content management systems: ATutor [208], LON-CAPA [209], and eZ publish [210]. The details of these open source systems can be described as follows:

ATutor and LearningOnline Network with a Computer Assisted Personalized Approach (LON-CAPA) are open source learning content management systems under the GNU General Public License. Both of these systems provide the capability for collecting course related information on the Web and adding links to manage them. Also they support teachers to create learning units in HTML or plain text. In addition, they offer the ability for staff to build and manage multiple forums for each of their courses where messages can be edited, deleted, and published. Furthermore, they provide the tools to monitor students' learning procedures, view course statistics, edit course preferences according to learners' requirements, manage the information of students, and delete a course from the system.

On the other hand, there are some different features between ATutor and LON-CAPA. The ATutor system is programmed in PHP based on MySQL database, and runs on any operating system [208]. The LON-CAPA software is programmed in C and Java over the Linux operating system, and mainly used in science and math in higher education. Also the LON-CAPA system provides an automatic grading system to assess learners' achievements, and an efficient assignment tool that can create unique homework and examinations for each learner in a group or a class, and the tools to feedback information to learners and instructors.

Compared with ATutor and LON-CAPA, the eZ publish system is distributed under dual open source licenses. That is, it can be used under the terms of the GNU GPL or the terms of the eZ publish Professional Licence that allows users to develop commercial software and solutions with the eZ publish. It is made in PHP for e-commerce and e-publishing, which is independent of operating systems. Access permissions in the eZ publish are controlled in terms of roles, which is another main difference compared with ATutor and LON-CAPA. A role is a set of access policies that can be assigned to a user or a user group. The role-based method allows users to specify access by module (content, shop, task, etc.), by function (read, create, edit, remove, etc.), by object owner, by object class, or by site section.

In this section, a set of open source e-learning systems were investigated. Next, as a part of this research background, we will discuss the Semantic Web and ontology concepts related to this thesis.

### **3.3. Semantic Web and Ontology**

In this section, we introduce the Semantic Web and ontology. Also the approaches of Semantic Web are analyzed. The relationship between the Semantic Web and ontology is discussed.

#### **3.3.1. Semantic Web**

The Semantic Web was proposed by Tim Berners-Lee who invented the World Wide Web and defined two layered architectures of the Semantic Web, such as the levels of ontology vocabulary, RDF, XML, and Unicode [211] [212]. The definition of Semantic Web from W3C [213] is represented as the following:

“The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries.”

The Semantic Web is a web of data, which can provide the ability for people to integrate all kinds of data (e.g. pictures and documents) in terms of users' particular needs in order to build their required Web services [214]. Furthermore, it can describe the semantic information of various real-world objects (e.g. the titles of books) with languages such as OWL and RDF (see section 3.5.1.), which facilitates users in finding interesting content from a lot of databases on the Web [215].

The aim of Semantic Web is to build conceptual models to represent machine-understandable semantic information (e.g. structures and meaning) of objects, which eventually will lead to efficient machine-to-machine interaction, knowledge mapping and organization techniques [216] [217]. So far, the World Wide Web provides little capability in supporting data aggregation to meet users' requirements [218]. For example, people always have to read, interpret, and organize search results before any useful information can be extrapolated. As there are a lot of different semantic associations to the objects that are searched, the results are varied in relevance. Computers only can list all of searched information for users who then have to do a lot of work to find their preferred information, because machines can not understand what information contains the most relevant data in a given circumstance. Through building the Semantic Web, data including the information from users (e.g. finding a book on the Semantic Web) is represented by machine-readable languages such as

RDF [219]. It means that computers can understand the semantic representation of people's requirements, such as a book title. This makes it easy for machines to find, assemble, and transform data according to users' demands [220]. Thus, the Semantic Web can allow people to manage all kinds of electronic information (e.g. data aggregation, searching, and automatic annotation) more efficiently than using the World Wide Web [218] [221].

So far, a lot of Semantic Web services and applications have been established, such as the Arcs and Nodes diagrams experiment produced by Dan Connolly [222]. This experiment developed an RDF model of the W3C process. Next, the model was applied to describe and reuse the semantic information of all sorts of resources such as a document. Also the model illustrates the possibility of facilitating the implementation of users' required services by using the Semantic Web technologies (e.g. semantic search). Furthermore, the Semantic Web application: CS AKTive Space [223] provides a set of methods (e.g. harvesting, scraping, content acquisition models) to aggregate a range of heterogeneous and distributed semantic information in computer science research. MuseumFinland [224] is a semantic portal that can support content search and presentation by using ontologies consisting of semantically interrelated collection of museums. Also PowerAqua [225] can translate questions written in natural languages into a set of logical queries, and give answers by assembling information derived from large-scale semantic markup distributed on the Web. In addition, Magpie [226] and the KIM (Knowledge and Information Management) platforms [227] provide a strong ability for automatic annotation. As a Semantic Web browser, Piggy Bank [228] can activate screen scrapers to construct information within any web page to be presented in the Semantic Web formats such as RDF and XML, which allows data to be processed by machines more easily.

The main features of Semantic Web are described as follows:

- Existing Semantic Web applications can take into account non-semantic resources from the conventional Web. For instance, an approach taken by the Magpie browser [229] can use subject-based ontologies (see section 3.3.2. for a definition of ontology) to augment the browsing of web pages (e.g. viewing more background knowledge relevant to a subject). The system automatically associates the information on a web page with an ontology that contains the subject matching with the information. Next, Magpie invokes the relevant services according to the content of this subject. Furthermore, a browser-based

tool called Piggy Bank allows users to write screen scrapers to scrape existing data out of web pages [228] [230]. Next, by aggregating all kinds of data from different Websites or combining public data with private data, users can get more information out of existing data. The platform TAP [231] can also extract data from all kinds of non-semantic materials on the Web by using aggregating data acquisition methods. Moreover, the system KIM [232] can aggregate the data from any Web page to build annotation.

- Existing Semantic Web applications can support either single-ontology or multi-ontology methods used to integrate semantic information. As a Semantic Web query system, AquaLog [233] can aggregate data from different ontologies and only one ontology can be operated at the same time. In CS AKTive Space, a specific ontology called the AKT Reference Ontology is used to support information aggregation from different data sources [234]. The feature makes the two systems to be suitable for semantic intranets where data is usually annotated by a single ontology. On the other hand, the systems of Piggy Bank [228] and PowerAqua [225] can be used to operate huge amounts of heterogeneous data in many varying formats from a lot of different ontologies. Thus, both of these tools can meet the demand of a large-scale Semantic Web where all kinds of semantic information from different ontologies may need to be aggregated.
- Existing Semantic Web applications can support the generation, searching, and reusing of semantic data. For example, CS AKTive Space [235] can produce semantic environments (rich navigation over the data) through using an underlying ontology consisting of elements (e.g. people, institutions, and papers) to acquire data from several different sources related to the study of computer science. As a semantic search system, TAP [236] can complete various searching tasks in terms of users' personalized demands based on the denotation of search queries and augmenting traditional search results with relevant information integrated from distributed sources on the Internet. Furthermore, PiggyBank [228] and PowerAqua [225] were developed to exploit semantic markup in order to find the ways on operating with semantic data.
- Existing Semantic Web applications are different in using new heterogeneous semantic information that was not described by users. An example of this is that PowerAqua can automatically use new data (e.g. RDF data from a particular Web site) to try and answer queries without any configuration effort. Compared

with PowerAqua, the tool CS AKTive Space [223] can only use the data that the system developers were collected from a set of interesting sites and represented by using the AKT Reference Ontology. It means that CS AKTive Space requires extra programming to make new information available.

- Existing Semantic Web applications can combine current web service techniques with their frameworks. An example of this is Magpie [237] that can aggregate services into its annotation mechanisms through dynamically connecting a selected item with all the relevant services. Here, if we chose an instance of class ‘researcher’, Magpie could automatically list all available services such as showing a set of projects that a researcher is involved in.

In the Semantic Web, there are a set of approaches that were developed. Here we present two methods: IRS-III [238] and OWL-S [239], which provide the capabilities for the development of Semantic Web services (SWS) and applications.

### **IRS-III**

The Internet Reasoning Service (IRS-III) [238] from the Open University is a Semantic Web services framework based on the Web Service Modelling Ontology (WSMO) [240]. The IRS-III platform uses a method (ontological description of semantic data) to support requestors to get their preferred services. In detail, IRS-III has a Semantic Web services (SWS) repository that is used to store semantic description of various aspects of Web services, involved domain ontologies and knowledge bases (instances). Next, the description is interpreted to discover and choose the appropriate Web services according to users’ requests. Then, the selected services are invoked with the relevant data, the control flow to Web service operations, and the invocation restrictions for the services. Finally, IRS-III can mediate any mismatches at the layer of data, goal or process through coordinating the semantic description.

A key feature of IRS-III is that through using a task centric invocation mechanism, users may simply design a task in terms of their particular requirements and the IRS-III broker locates, invokes, and integrates the corresponding Web service [241]. IRS-III provides an IRS-III browser for the developers of Semantic Web services, which facilitates the navigation of knowledge, and the description, publishing, and invocation of Semantic Web services in terms of the individual requirements of developers. Also by using the Java API, the IRS-III framework can combine a list of

tasks to become one application, which helps users to aggregate semantic information according to their individual needs. Furthermore, the software IRS-III can support Web services based on WSDL (section 3.4.4.) description, stand-alone Java codes, and Web applications available as HTTP GET requests. It can facilitate users to create standards-based Semantic Web services, which makes it easy to interact with existing Web services distributed on the Internet.

The overall design aim for the Semantic Web based method used by IRS-III is to build varieties of semantic relationships between users' demands and deployed Web services available on the Internet [238] [242]. The approach can be seen as mediation itself and is further broken down into data, goal, and process mediation which are reflected by a set of specific modules in the architecture. In order to support this core function, the IRS-III mediation handler was designed and is illustrated in the following figure in which components are labelled in bold and semantic descriptions are labelled in italics [238].

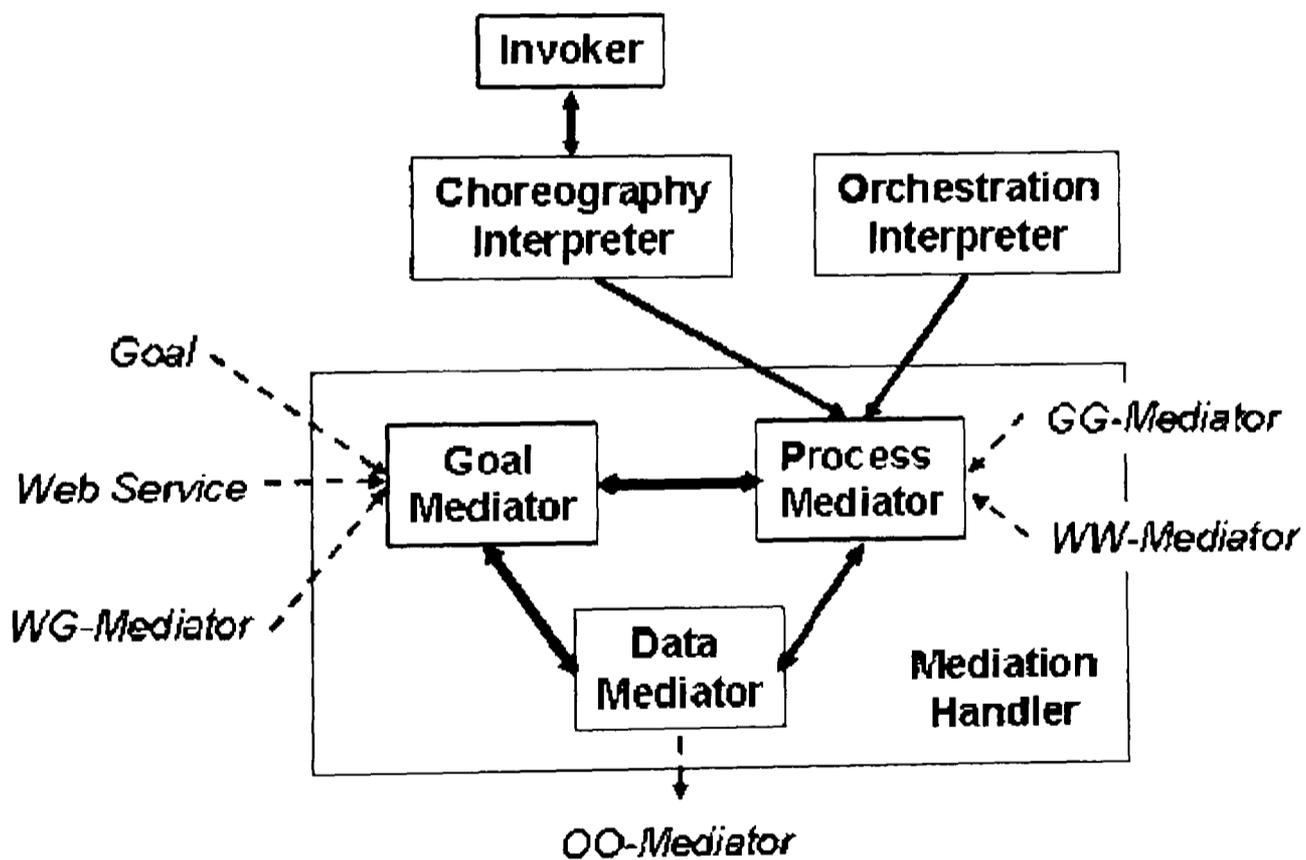


Figure 3.1 The IRS-III Mediation Handler

The general sequence of mediation activities relating to the composition and invocation of Semantic Web services is described as follows [238] [240] [243]:

- The Goal Mediator component searches for wg-mediators (linking a Web service to a goal and resolving mismatches between Web services and goals) to get the source component that can be suitable for the demands of a user delivered by a client application. Next, a Web service is selected by the source component to

- match with the requested capabilities such as input types, preconditions, assumptions, and non-functional properties. Here, the mismatches are reflected by distinguishing the input types of a goal from the input types of the target Web service, and measuring the number of the inputs of the Web service and the goal.
- The Process Mediator component can execute personalized Web service operations to interact with a deployed Web service. This mediator produces the communication messages to reflect the content of a process (e.g. all kinds of operations to the target Web service from the Goal Mediator). Also the state of the communication with the target service is recorded by the mediator to allow an invoker component to run the requested operation calls in the designed sequence.
  - The Process Mediator can also aggregate a set of Web services in terms of the orchestration (control and data flows) from the Goal Mediator. In detail, the Process Mediator can invoke sub-goals (all kinds of operations) to the services in the requested order. Furthermore, the mediator searches for gg-mediators to build the bridges between sub-goals according to the orchestration designed by a requestor. Also the gg-mediators (defining goal ontologies to store predefined goals and specifying users' goals such as buying a train ticket by reusing existing goals) can indicate the mismatches occurred between sub-goals in a data flow, which can be resolved by the declared mediation service. The mismatches can show the difference between the output types of a sub-goal and the input types of the target sub-goal, the different orders between the output values of a sub-goal and the inputs of the target sub-goal, and the relationships between the output of a sub-goal and the inputs of the target sub-goals (e.g. a part of the output can be regarded as an input).
  - The Data Mediator component can use oo-mediators (processing domain ontologies, such as merging a train connection ontology and a purchase ontology to be a train ticket purchase ontology) to complete the requested mapping to associate varieties of data across domain ontologies, and transfer the results to the Goal Mediator and the Process Mediator.

## **OWL-S**

The OWL-S platform from DAML [244] is a mechanism used to create a variety of OWL-based (section 3.4.1.) Semantic Web services ontologies, which can provide highly expressive concept-forming constructs including the properties and

capabilities of services [245] [246]. It models the characteristics of web services to generate semantically enriched description of services. OWL-S can explicitly represent the concrete input/output messages and specify how they are linked to parameters in a concrete message mechanism. In detail, a mapping is built between each input/output parameter of an OWL-S process model and its relevant target parameter in a document written in Web Services Description Language (WSDL, see section 3.4.4.). Furthermore, other parameters (e.g. operation name and a URI pointing to a WSDL document) are described. As OWL-S focuses on the area of upper ontology, it does not provide domain ontologies that have to be completed by service communities. The method can create specific service description by using classes that can be instantiated by a service provider [247]. The OWL-S approach consists of two main building blocks: OWL-S virtual machine and matchmaker, which can complete the composition, discovery, and invocation of Web services and applications by using OWL. Also users can use an OWL-S Virtual Machine to control the interaction between web services through integrating the relevant OWL-S processes [248]. In addition, OWL-S can be used to describe the agent functionalities in multi-agent Systems, such as the representation of the semantic information of a task.

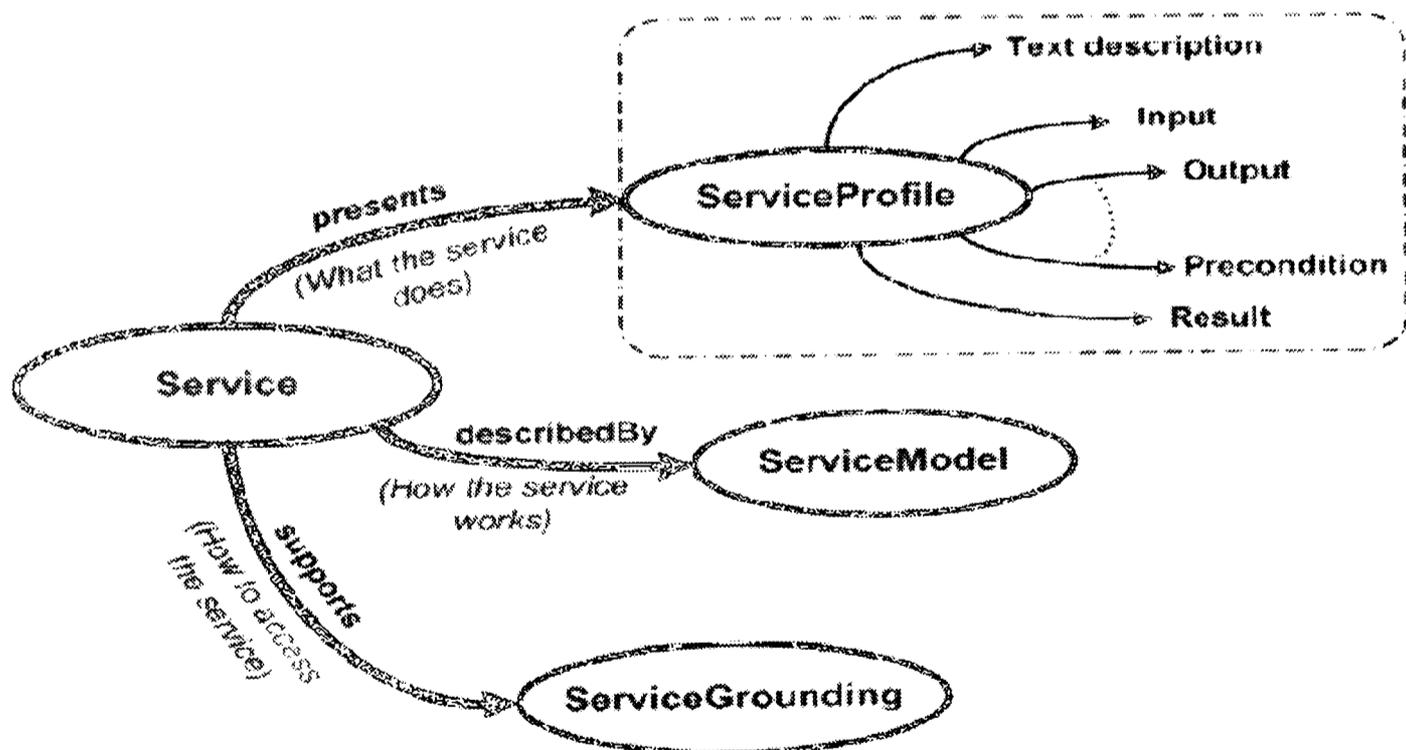


Figure 3.2 OWL-S based Description of a Web Service

The method OWL-S designs three modelling constructs that are illustrated as the above figure [245]:

- The service profile can provide a representation of the capabilities of web services (e.g. what the service does) through the text description of the functionalities of services.

- The service grounding explains how the service can be accessed through transforming the messages into the WSDL compliant form in terms of the format and input/output specification in the process model.
- The service model gives a detailed description of how to use the service in terms of semantic information including its workflow. That is, the model can specifically describe the transformations (e.g. the processes) that it undertakes to show how the service operates.

### **3.3.2. Ontology**

Ontology is a scientific description mechanism to represent the semantic information of objects, including the descriptions of types, relationships, and their instances [249]. It refers to metadata-based semantic-structured underlying data collections to objects [250]. The main function of this mechanism is to aggregate the semantic information of objects in terms of the practical requirements of humans in a formal way such as OWL and RDF [251] [252]. The aim of the mechanism is to build a conceptualization specification of a knowledge domain, in which all kinds of semantic information (e.g. the relationships among objects in a domain) can be specified, shared, and reused in a consistent standard [253] [254]. This conceptualization specification refers to the identification of the relevant concepts of a phenomenon in the world through using an abstract model of this phenomenon.

In general, standards-based ontologies play a key role in the construction of Semantic Web services and applications [255]. Ontology technology can describe all kinds of semantic information of Web services and applications according to users' particular demands in the machine-processable formats such as RDF, OWL, and XML (section 5). Furthermore, through building varieties of shared, reused, and users' requirements-oriented ontologies for specific knowledge domains, ontology technique makes it easy for humans to aggregate their interesting heterogeneous resources (e.g. semantic knowledge, non-semantic knowledge, conceptual knowledge, and non-conceptual knowledge) from different information systems [256]. Finally, ontology technology provides the strong functions in the exchanging of semantics of Web services and applications [257]. Therefore, the creation, use, and management of ontologies based on people's personal requirements is crucial for the successful building of the Semantic Web.

There are some basic elements that creators should grasp before building ontologies according to the actual demands of users [258] [259] [260]. In detail, it requires the authors of ontologies to have a good background knowledge of the area which they plan to represent. For example, designers need to have a general understanding about a learning unit (e.g. the goal and content of education, and the position in a learning process). Next, they may create ontologies to reflect the relevant semantic information, such as the title and description of the unit, and the relationships between the unit and others. Furthermore, it is very important to obtain the practical needs and questions in this area before making ontologies. For instance, in the e-learning area, according to the requirements of learners and teachers, ontology creators may need to composite different kinds of learning units, such as lecture, forum, and exam.

Next, the Computing Curricula 2001 (CC2001) [261] is used as an example to present ontology generation (describing and assembling semantic information about a curriculum according to users' individualized requirements such as a particular order between units), applications, and values. CC2001 was developed by the Joint IEEE Computer Society/ACM Task Force on the "Model Curricula for Computing". As CC2001 focused on the area of computer science (CS), it has been relabelled as CS2001 [262]. It describes a set of concepts about curricula designing and implementation (e.g. core and elective units and topics), which are used to guide educators to do curricula revision, discipline definition, topic classification, and assessment on curricula. The detailed information is analyzed below.

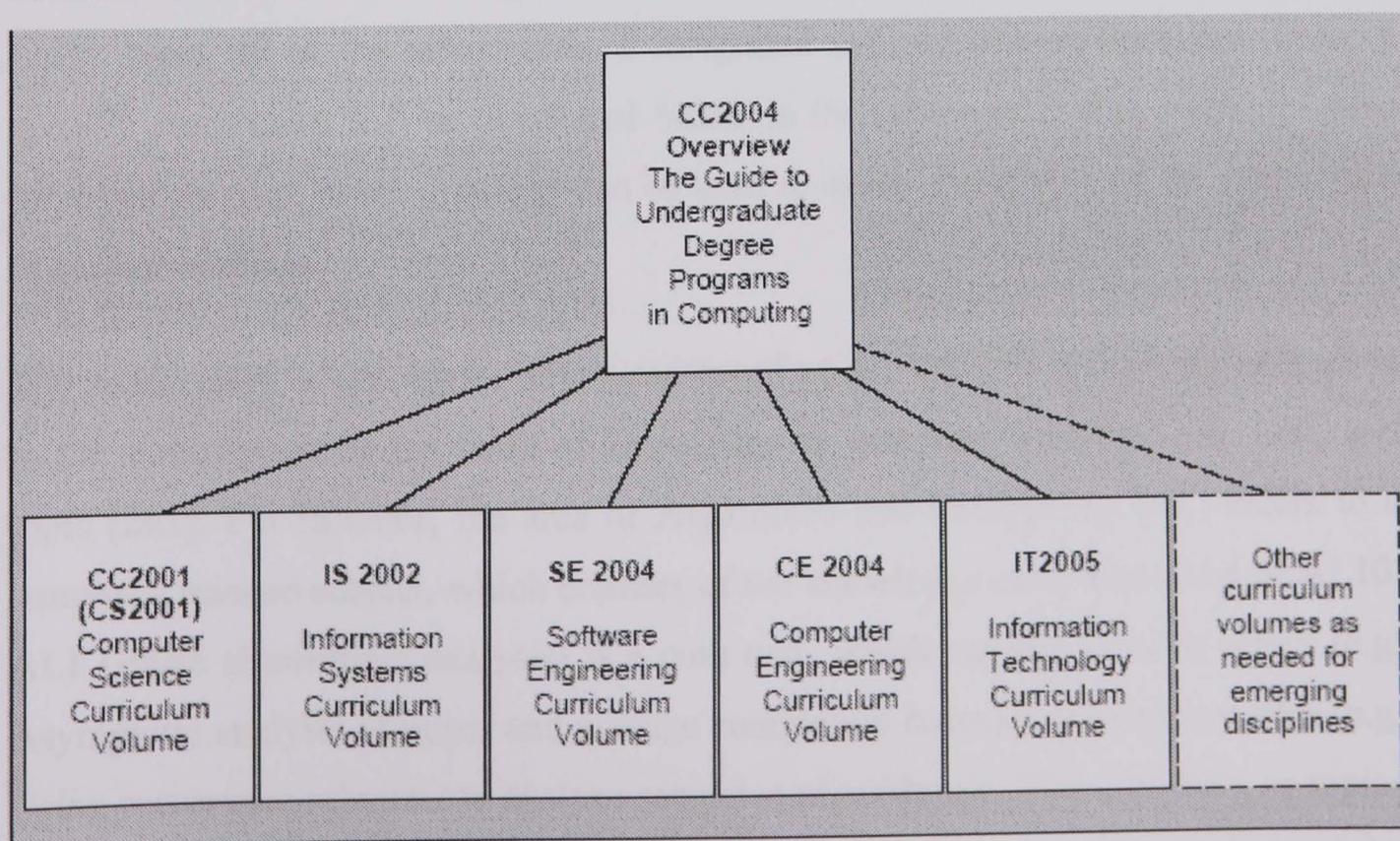


Figure 3.3 Disciplines in Computing

The Computer Science Curriculum Volume (CS2001) contains curriculum recommendations for undergraduate programming courses in computer science. In addition, some other volumes were developed to guide undergraduate programs in computing such as computer engineering (CE), information systems (IS), and software engineering (SE), which are shown in the above figure [262]. The overview volume (CC2004) describes the differences and similarities of these computing subjects, and the relationships between them. Other volumes (e.g. CS and IS) are discipline-specific, which concerns the detailed specifications of the curriculum cores in their disciplines, some curricula as models for education, and the guidelines for implementing a curriculum. The goal of these guidelines is to represent the notions that computing instructors should be aware of when designing and implementing a computing curriculum. It is helpful for educators to produce educational processes with high quality.

The Joint Task Force from IEEE Computer Society/ACM structured the body of knowledge with the similar method for each computing subject (e.g. CS and IS) in order to build an undergraduate course standard of the relevant area [262]. Here, the CS2001 is used as an example to show how to build various ontologies to direct the designing and implementation of users' individualized curricula in computer science [263]. The core function of this model is to use a series of notions (e.g. core units and topics) to describe the semantic information about a course in terms of instructors' requests, such as which core units and topics should be adopted, what sequence between units should be designed, and which course level should be chosen [264] [265]. Next, all of the information is integrated and put into an ontology. Then, a specific curriculum will be developed based on the messages in this ontology. Also the concepts used in the ontology can be used to assess the quality of the curriculum or further revise it.

The architecture of ontologies developed based on the CS2001 is designed according to the three layers of the body of knowledge in computer science: area, unit, and topic [261]. For instance, the area of Algorithms and Complexity (AL) refers to a computer science subject, which consists of ten knowledge units from AL1 to AL10. AL1 (Basic algorithmic analysis) is a core unit, which consists of core topics (e.g. Asymptotic analysis of upper and average complexity bounds) and elective ones (e.g. Using recurrence relations to analyze recursive algorithms). The core units or topics refer to those items required of all students in all computer science degree. An

application of these elements was implemented by Krishnaprasad [264]. It assembled the core units and topics in the areas of Programming Fundamentals (PF) and Algorithms and Complexity (AL), and produced three new courses such as “CS1: Programming I and Data Structures. PF1, PF2, PF3, AL1, some AL3” and “CS3: Algorithms and Complexity. AL1 (depth), AL2, some AL3, AL4, AL5.”. Here, PF1, PF2, and PF3 are core units in Programming Fundamentals. The new “CS3” is very different from the courses used before such as “CS3: Data Structures and Advanced Programming. PF5 (depth), PF6, some PF7, some PF8, some AL1, some AL2, some AL3” [264]. The emphasis of the new “CS3” curriculum has been shifted from PF to AL in order to match with his educational goals. It means that all kinds of units and topics as well as other concepts defined by the task force can be selected and aggregated according to users’ particular demands (e.g. different educators may have different curriculum goals to a course).

Furthermore, through using the concepts (e.g. units and topics) provided by the CS2001 [261], it can facilitate users to design a curriculum that will be taught for the first time [263]. People may collect the information (e.g. educational aims) about a new course and associate it with the content of CS2001 such as core and elective knowledge units and topics, core teaching hours, and learning objectives. Then, the selected elements (e.g. some core units) will be assembled to be an ontology that contains the semantic information of a new curriculum. Educators may author the new course based on this ontology.

Finally, the notions in the CS2001 can be used to improve the quality of existing courses [263]. For instance, the CIS department of the Washburn University adopted the units, topics, and other elements defined by CS2001 to evaluate their CIS curriculum. They found the course can meet the most requirements of the model curriculum in CS2001. Also they captured and corrected some deficiencies, such as changed a few topics and redesigned the sequence between some units (changed the semantic information in the relevant ontology). That is, through comparing existing curricula with CS2001 concepts and paradigms, users can optimize the contents and structures (e.g. the orders between units) of the curricula, which is very important for achieving educational aims.

So far, the Semantic Web and ontology have been discussed. Next, the standards proposed to use in this research will be analyzed.

### **3.4. Main Standards**

Standards can be defined as specifications for general or particular subjects, which aim to provide the best or most appropriate mechanisms or methodologies to complete tasks. For example, we may build an XML document based on XML standards. In the e-learning area, standards can be the high-level infrastructure on which systems and applications are made. These standards are the base to enable flexible and upgradeable features, and interoperable abilities. In brief, standards can provide a basis for a variety of e-learning applications. One of the functions of standards is that if a new system is built based on the standards on which existing applications were established, then this new application can communicate with these legacy applications. Another function is that standards can make it easy for systems or applications to be deployed on the Internet, as they are designed on standards that support the Internet standards such as TCP/IP and HTTP.

There are many standardization organizations [266], such as ISO (International Standardization Organization), IEEE LTSC (Learning Technology Standards Committee), W3C, IMS, ADL, DCMI, ISO/IEC, AICC (Aviation Industry CBT Committee), GEM (Gateway to Educational Materials), and EdNA (Education Network Australia). The standards developed by these organizations are mainly in three areas: metadata, packaging learning resources and learning design. We mainly discuss a set of standards which play the crucial roles in this research.

#### **3.4.1. Metadata Standards**

Metadata refers to data about data, which is structured descriptive information about objects. For example, metadata can be regarded as subject name, subject URI (Uniform Resource Identifier), subject description, status (whether available), date issued, and subject board (containing additional information of this subject). We introduce five commonly used metadata standards in the following paragraphs.

##### ***IEEE LOM***

The IEEE LOM (Learning Object Metadata) [267] is a standard developed by IEEE LTSC LOM working group, which specifies the syntax and semantics of learning object metadata. The latest version of the IEEE LOM standard is IEEE P1484.12.2/D1. It defines a learning object (digital or non-digital) as an entity, which can be reused and managed to support computer-based instruction. Compared with the following standards, its main feature is that this standard is extensive and

complete. It defines a number of attributes for terms, which can be used to represent any detail of a learning object. This leads to a problem of too many attributes to be used to describe a learning object.

### ***IMS Metadata Specification***

The IMS Metadata Specification [268] is based on the IEEE LOM Meta-data Scheme working document and the modifications approved by the IMS Technical Board. It comprises three documents: IMS Learning Resource Metadata Information Model, IMS Learning Resource Metadata XML Binding Specification, and IMS Learning Resource Metadata Best Practices and Implementation Guide. The latest version of IMS Meta-data Specification is V1.2.2. These standards define attributes for each element in nine categories as defined in the IEEE LOM such as general information, technical, and classification of learning resources. The main difference between the IEEE LOM standard and the IMS metadata specification is that the IEEE LOM predefined a lot of elements to describe all the information of learning objects' properties. It is clear that generally users do not need to describe all properties of learning objects. On the contrary, the IMS Meta-data Specification provides a strong capability to build extension elements through the use of DTDs or XML Schema Definition Languages (XSD and XDR). These extension elements can be dynamically created by users, which are used to describe the required learning objects' properties.

### ***RDN/LTSN Resource Type Vocabulary***

The RDN/LTSN Resource Type Vocabulary [269] published in September, 2003, defines a vocabulary used to specify learning objects, especially the type of them. It is designed to be used with the IEEE LOM or DCMI standards. The main difference from the DCMI standard is that it provides a lot of attributes to describe the types of learning objects, such as "CourseLecturePresentationNotes", "Glossary", "CurriculumSyllabus" and "ActivityExerciseFieldworkNotes". Furthermore, it is simpler than the IEEE LOM standard, as the number of attributes is much less than the number of attributes in the IEEE LOM standard.

### ***UK LOM Core***

The UK LOM Core [270] from CETIS is a specification providing common practice and guidelines for the implementation of the IEEE LOM in the UK higher and further education. The latest version of this standard is V0.1. It designs a set of

metadata elements (e.g. terms) to be used in an educational context. This standard defines mandatory and optional elements in the nine categories based on the IEEE LOM standard, and offers implementation guidance. It can be very helpful in defining best practice when using the IEEE LOM standard to describe learning objects, as it cuts the size of attributes defined by the IEEE LOM.

### ***DCMI***

The Dublin Core Metadata Initiative (DCMI) [271] developed a set of interoperable online metadata standards such as DCMI Core Metadata Element Set, DCMI Type Vocabulary, and DCMI Metadata Terms, which are used to simply describe a broad range of objects in distance learning for improving the efficiency of information discovery systems. The latest version of DCMI is V1.1. A DCMI term is defined by a DCMI recommendation that is a human-readable document. Also the minimum set of attributes is defined for each DCMI term, such as name, URI, label, comment, and reference. The current efforts are in the technical architecture to support learning resources discovery, and the collaborative development and perfection of metadata conventions based on research and feedback. The main features of the DCMI standards are that they use simply-understood semantics for elements that can be used by non-catalogers as well as resource description specialists; increasing the ability of semantic interoperability through providing a common description of elements and attributes; and providing sufficient flexibility and extensibility to encode the structure of learning resources. The attributes provided by the DCMI standard however are not enough to fully describe learning objects, which only represent part features of them. For example, there are no attributes used to describe the type and context of information of learning objects.

Generally, the IMS Metadata specification and RDN/LTSN Resource Type Vocabulary can be regarded as the summarized versions of the IEEE LOM. The DCMI can only provide simple descriptions of learning objects without considering their context. In our research, we intend to choose the UK LOM Core and IEEE LOM to implement metadata design, because the IEEE LOM describe all aspects of metadata design and the UK LOM Core is one of the best practical profiles of the IEEE LOM.

## ***OWL***

Web Ontology Language (OWL) [272] is a Web standard created by W3C for machine-interpretable description of information of objects. It was designed to be read by computer applications, not for being read by humans. OWL focuses on building a standard way to assemble the semantics of web information in a unit (e.g. a learning unit) rather than displaying them. It is built based on RDF and implemented in XML. There are three sublanguages in OWL: OWL Lite, OWL DL (includes OWL Lite), OWL Full. OWL is an extension of RDF and includes OWL DL. Also OWL Lite is part of OWL DL, and both of them are restricted extensions of RDF. That is, RDF and OWL Full documents can be transferred to each other, and only some RDF documents can be transferred to OWL Lite or OWL DL formats [273]. So in this research, I will use OWL Full and RDF standards to make sure the free delivery of data with different formats. The main difference between OWL and RDF is that OWL can provide the stronger function in machine interpretability, a larger vocabulary, and stronger syntax than RDF [274].

## ***RDF***

Resource Description Framework (RDF) [275] is a general XML framework from the W3C, which aims to support describing and interchanging metadata that any Internet resource (e.g. a Web site and its content) comprises. RDF is a formal data model to represent various web resources by using machine-readable metadata. The main functionality of RDF is to describe simple metadata of all kinds of resources on the internet, such as the structures of sitemaps and the personalized property rights of Web pages. RDF documents are completed in XML that is called RDF/XML. Through using XML, RDF information can easily be delivered between different types of operating systems or applications. As RDF is designed for computers to read and understand, so it can easily support interoperability among computers and applications on the Web, such as exchanging information in online shopping systems, Web events schedule systems or digital library systems.

### **3.4.2. Standards For Packaging Learning Resources**

There are standards that have been developed to be used as the specifications to package learning resources including learning content and users' information. Here two widely-accepted standards are discussed, which are very useful for this research.

### ***IMS Content Packaging***

IMS Content Packaging [276] is a set of specifications to describe the structure, packaging, and exchange of learning materials such as courses into interoperable and distributable packages. It consists of three documents: IMS Content Packaging Information Model, IMS Content Packaging XML Binding Specification, and IMS Content Packaging Best Practices and Implementation Guide. The latest version of IMS Content Packaging is V1.1.3. It designs a conceptual model made up of four components: package interface file, manifest, physical files, and external packages. In practice, it uses a special XML file to describe the content organization and resources in a Package, and uses the physical files to store the actual content including media and assessment information.

### ***IMS Learner Information Package Specification***

IMS Learner Information Package [277] is a mechanism to package learner information and exchange it between learner information systems or between learner information systems and other systems (e.g. course delivery systems) supporting distance learning on the Internet. The latest version of this standard is V1.0. It is also divided into three parts: IMS Learner Information Package Information Model, IMS Learner Information Package XML Binding Specification, and IMS Learner Information Package Best Practises and Implementation Guide. It defines a set of attributes to describe learners' information, such as identification, transcript, interest, and process. But these attributes are only limited to learners, and can not be used to describe other users in virtual learning environments, such as instructors, authors, evaluators, and administrators.

### **3.4.3. Standards For Learning Design**

Learning design can be defined as a mechanism to define and design elements (units of learning, e.g. courses, modules, or lessons) to describe learning procedures in a certain order in a formal way. A unit of learning is an independent piece of education or training, which contains learning content and learning activities such as search activities, discussion activities, and group building activities.

### ***IMS Simple Sequencing Specification***

IMS Simple Sequencing [278] defines simple learning procedures and activities according to learning experiences, so that learning technology systems can sequence separated learning activities in a consistent way. Its latest version is V1.0 consisting

of three documents: IMS Simple Sequencing Information and Behaviour Model, IMS Simple Sequencing XML Binding, and IMS Simple Sequencing Best Practice and Implementation Guide. This specification defines a sequencing process that comprises navigation behaviour, termination behaviour, sequencing behaviour, and delivery request behaviour. By running this process, learners can obtain the learning content and complete the relevant learning activities. Briefly, this specification can be regarded as a simple implementation example of the IMS Learning Design standard.

### ***EML***

The Educational Modelling Language (EML) [279] developed by the OUNL (the Open University of the Netherlands) is the first system to allow users to codify units of learning including their contents, roles, relations, and activities from pedagogical perspective. So far, it is mainly implemented by XML and its latest version is V1.0. EML can be used to model a variety of learning objects, such as rights control based pedagogy, learning action support, self-learning packages, and traditional face-to-face teaching. The main feature is that the EML standard can provide interoperability, reusability, and compatibility of learning content. It is a generic and flexible language to model a variety of pedagogies.

### ***IMS Learning Design***

IMS Learning Design [280] aims to develop a common framework for pedagogical diversity and innovation based on EML. The latest version of IMS Learning Design is V1.0 and includes three parts: IMS Learning Design Information Model, IMS Learning Design XML Binding Specification, and IMS Learning Design Best Practises and Implementation Guide. It specifies three levels of implementation: level A contains all the core vocabularies, level B adds properties and conditions to level A, level C adds notification to level B. This standard also defines a number of attributes to describe learning processes, such as identifier that is a unique ID of a learning design file and sequence-used that indicates whether IMS simple sequencing is included in the document instance.

The IMS Simple Sequencing is a practical application of the IMS Learning Design, which is only for simple learning processes. EML is a high-level framework to represent learning procedures from pedagogy, so it does not give the enough low-level technique implementation details of learning design. Compared with these two

standards, IMS learning design can be regarded as a good solution to complete learning design. There are two main reasons why we prefer IMS learning design. One reason is that IMS learning design can describe not only simple learning procedures but also complex ones, which can be used to represent all kinds of learning processes including self-control, cooperative or taught learning processes. Another reason is that IMS learning design shows the direct ways of low-level technical descriptions of learning procedures, such as it defines a set of terms, properties, and notifications to describe concrete learning processes, analyses how to use XML technology to represent learning procedures, and gives some practical examples of learning processes. So IMS learning design can be understood and used more easily than EML. In sum, we may use XML elements to transform learning processes into XML schemas, and the specification of IMS learning design best practice and implementation guide can facilitate us to transform these schemas into applications to dynamically control specific learning processes.

#### **3.4.4. Web Standards**

Apart from the standards mentioned above, there are several standards of interest, which are not particularly designed for building virtual learning environments. As most existing and future e-learning systems are built on the Web, so these standards also play the same important roles as the standards discussed above.

#### ***XML***

The Extensible Markup Language (XML) [281] derived from SGML (Standard Generalized Markup Language published by ISO) is a text-format language, which is so far the most important standard to exchange a wide variety of data on the Web. This standard was completed by the W3C organization in 2000 and its latest version is V1.0. It separates the data itself and the data presentation. One of the main features of the XML standard is that it is an efficient mechanism to describe any object and make an XML file that can be delivered across platforms and networks. In our research, we regard the XML format as the bridge to exchange files between one format and another by using metadata technology. That is, a file is transformed into an XML format that will be then transferred into other formats such as HTML and Rich Text formats.

## ***XSLT***

The Extensible Stylesheet Language Transformations (XSLT) [282] developed by the W3C organization is a language to transform an XML format into other XML formats or non-XML formats such as HTML and text formats. The latest version of this standard is V1.0. It defines the style sheet structure, data models, and templates used in XML documents. The main achievement of the XSLT standard is that it offers a general platform for uses to change the formats of files, which can meet the requirements of multiplicity of resources presentation on electronic devices such as portals and Palms.

## ***SOAP***

The Simple Object Access Protocol (SOAP) [283] produced by the W3C organization is an XML-based, lightweight standard to exchange information about software objects in decentralized and distributed environments on the Web. The latest version of the SOAP is V1.1. This protocol provides an information message that consists of three components: an envelope that is a methodology used to describe what is in a message and how to process it, a set of encoding rules for representing the actual content, and a convention to describe remote procedure calls and responses. The main feature of this protocol is that it can be used in combination with a variety of other protocols such as XML, XSDL (XML Schema Definition Language), HTML, UDDI, and WSDL.

## ***WSDL***

The Web Services Description Language (WSDL) [284] developed by the W3C organization is used to describe Web services including document-oriented and procedure-oriented information in an XML format, which can be performed by the end users on the Internet. The latest version of the WSDL is V1.1. The outstanding advantage of this standard is that it provides the ability to represent messages independent of the message formats adopted by these messages, so it can be used with XML, SOAP, and HTTP standards together. A package in which the WSDL is used to describe a Web service can be integrated into a SOAP box, as both the SOAP and the WSDL are built based upon the XML standard.

## ***UDDI***

The Universal, Description, Discovery and Integration (UDDI) [285] standard completed by the organization for the advancement of structured information

standards (OASIS) is an interoperable framework to allow users and applications to easily, quickly, and dynamically find and use Web services on the Internet. This standard can support W3C standards such as XML and HTML, and the standards from the Information Engineering Task Force (IETF) such as the Domain Name System protocol. Its latest version is V3.0. It was designed to be cross-industry and its information can be added into SOAP packages, so it is valuable for users to convey information between virtual learning environments and the systems or applications in other industries.

The standards related to this thesis have been discussed. Next, three examples of VLEs and the technical research problems are to be represented.

### **3.5. Three Scenarios of Existing E-Learning Systems**

#### **3.5.1. Why Select these Tools**

In the work reported here, we studied a set of existing e-learning systems: LAMS [286], RELOAD [287], WebCT [288], ATutor [208] [289], KEWL [290], and Blackboard [291]. The goals of this research focus on three aspects: supporting a range of teaching styles, the personalized creation of instructional processes, and the individualized control of these processes. Thus, the selected e-learning systems should be valuable for the implementation of research aims. It means that the chosen tools should present a series of characteristics that can give the thesis insight into how to implement the flexible designing and control of educational processes according to users' individualised needs. The detailed messages about this topic were shown in the following paragraphs in which LAMS, RELOAD, and WebCT are discussed. Furthermore, there could be some other e-learning systems that are suitable for the selection criteria mentioned above. As the thesis aims to achieve flexible e-learning and not compare existing e-learning tools, it is not necessary to import all appropriate systems into the research.

The reasons why these three e-learning systems were selected can be described as follows:

- LAMS is very helpful for this research in the building and controlling of instructional procedures [292] [293] [294]. LAMS provides the ability of the creation and management of educational processes. For instance, LAMS identified instructional services, such as chat, noticeboard, grouping, Q and A, survey, multiple choice, and forum. A teacher may select part or all of these services and array them in a specific order to establish his/her interesting

educational procedures. Furthermore, LAMS can support instructors to track and monitor the learning procedures of students, which provides the convenience for staff to manage these processes. These functions produced the valuable influence for the research in how to implement the individualized authoring and control of educational procedures, such as the idea of “locking learning units” in the thesis derived from the ability of sequencing learning content of LAMS.

- The main value of RELOAD for the research is that the software can represent the rich semantic information of learning units and author users’ preferred units [295] [296] [297]. It can describe a set of semantic data of units, such as the name, identifier, and description of a unit, the relationships among the units in a learning content package, and the standard that a unit is built on. Furthermore, RELOAD can allow users to import their interested learning resources distributed on the Internet with different formats into the RELOAD editor environment, such as a picture, a PDF file, a Web page, and a Word document. Next, these resources can be aggregated to be standards-based (e.g. IMS Metadata Specification) ontologies that contain the information required by users, such as the titles and addresses of the pictures selected by users, and the particular order that each user designed between the chosen graphics. In sum, RELOAD provided the valuable experience for the thesis in how to represent the semantics of learning units according to users’ demands and how to build users’ interesting ontologies (instructional content packages) based on standards through integrating different types of learning materials.
- WebCT is a widely-used e-learning system that provides a lot of functions in designing and managing interactive educational processes according to users’ requirements [288] [298] [299]. The system provides a set of tools in virtual communication and management, such as group synchronous and asynchronous communication (e.g. discussion board and chat room), viewing any learner’s progress by a teacher, and online storage and presentation of students’ work. All of these technologies show what learners have done, what learners are doing, and how data related to students’ learning are used. In addition, by using the tool of online assessment, WebCT can provide a good evaluation on coursework. It was proved that WebCT had no unfriendly effects on learners’ examination behaviours [299]. Moreover, this software can create learning materials complying with the demands in actual use, such as a test with time limitation. In

summary, WebCT is a valuable reference in studying the usability issues (e.g. teacher control and learner management) of e-learning systems.

The more detailed information of LAMS, RELOAD, and WebCT are analyzed in the following.

### 3.5.2. Learning Activity Management System

Learning Activity Management System (LAMS) [286] is an environment to design, manage, and transfer learning activities (section 1.1. of Chapter 1), which is built by James Dalziel based at Macquarie University E-learning Centre of Excellence (MELCOE). The LAMS system provides the ability for teachers to author simple sequences between learning activities (e.g. drag and drop one activity behind another) and to monitor learning processes of students (e.g. which activity a student is doing) [300] [301]. The creation and execution of activities by using this tool can be shown in the following diagrams 3.4 and 3.5 [201].

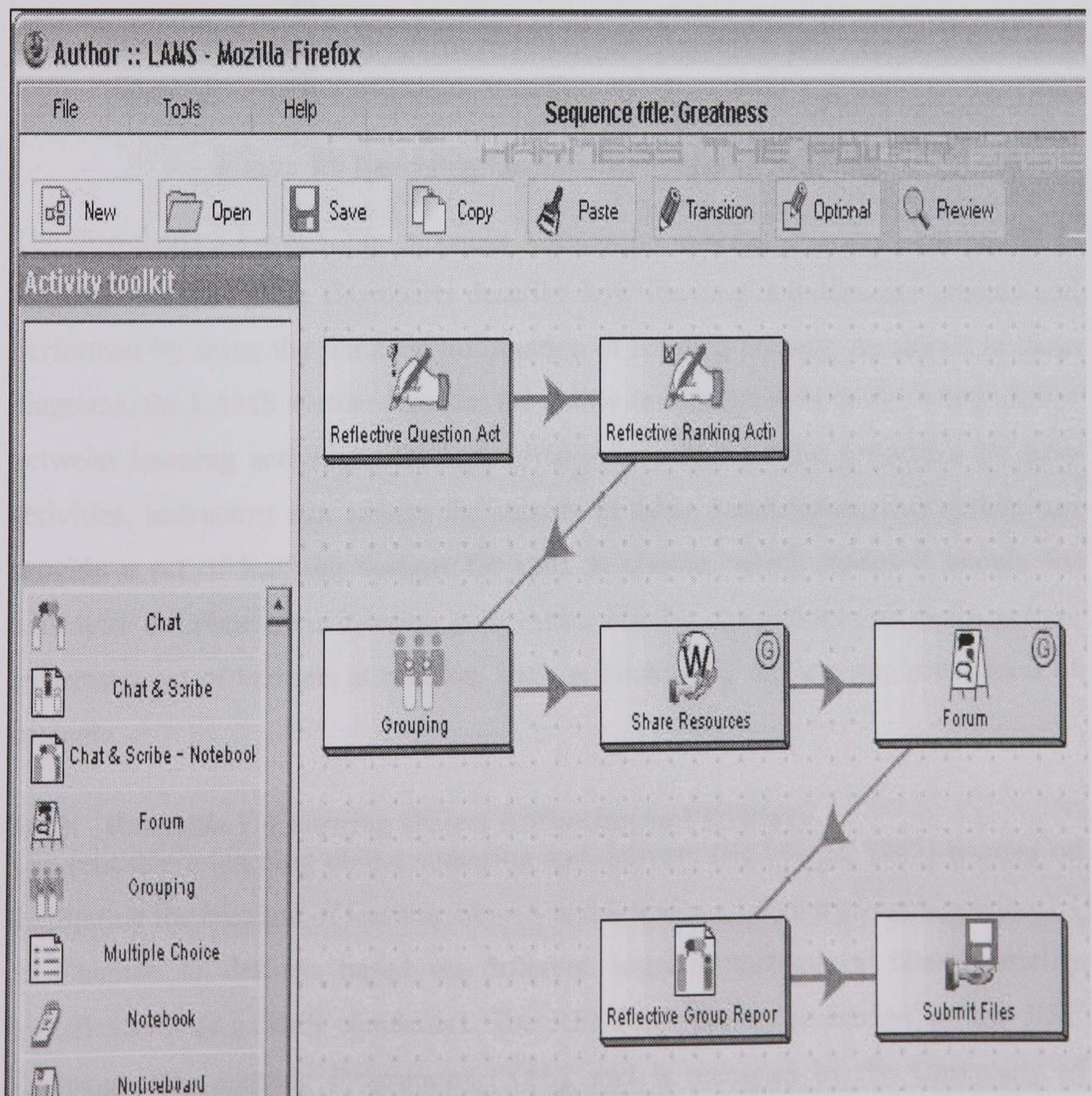


Figure 3.4 Authoring the Sequences of Learning Activities by Teachers

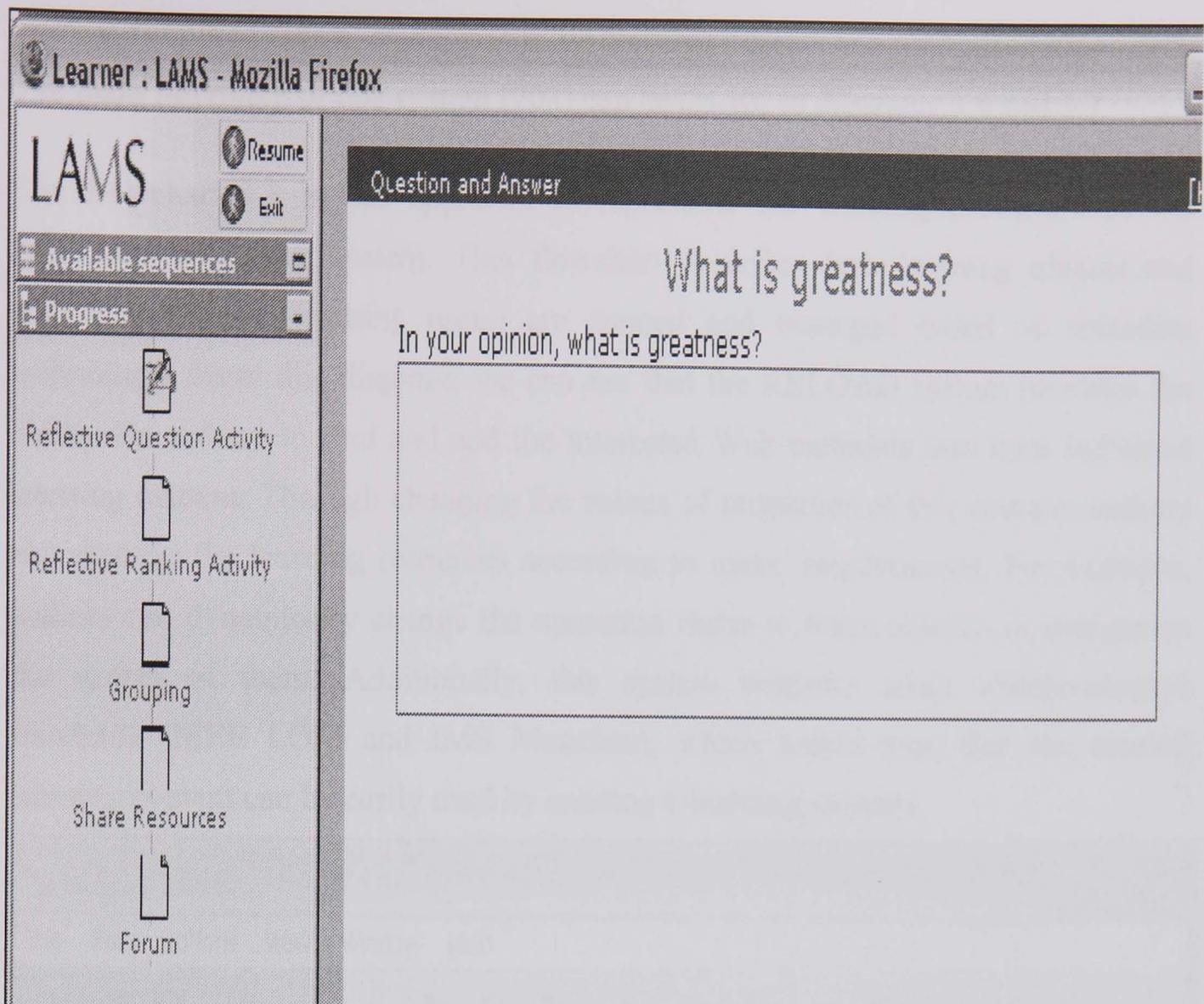


Figure 3.5 Executing Learning Activities by Students

The flowcharts 3.1 and 3.2 in appendix A show the working process of the LAMS e-learning system. These flowcharts describe how learning activities are created and performed by using the semantic information of learning content. As shown in these diagrams, the LAMS system provides the ability for educators to design relationships between learning activities. Through giving the values of the properties in these activities, instructors can change the content in them. Furthermore, this system can provide a set of learning designs for staff to choose, which makes it simple for educators to create their learning procedures. Finally, instructors can easily get the circumstances of learners at runtime, such as monitoring the learning procedures of students.

### 3.5.3. Reusable E-Learning Object Authoring and Delivery

The reusable e-learning object authoring and delivery (RELOAD) [287] focuses on facilitating the creation of learning objects and learning content packages (section 1.1. of Chapter 1) defined based on different learning technology interoperability specifications (e.g. IMS standards). The RELOAD project is funded by the JISC Exchange for Learning Programme (X4L), and is managed by the University of Bolton and the University of Strathclyde. The main aim of the RELOAD system is to

make it simple to create, share, and reuse learning objects and packages [296] [297]. The main interfaces of this system [202] can be shown as diagrams 3.6 and 3.7.

The flowchart 3.3 in the appendix A represents the working procedure of the RELOAD e-learning system. This flowchart describes how learning objects and content packages (learning units) are created and managed based on metadata technology. From this diagram, we can see that the RELOAD system provides the ability for authors to find and add the interested Web materials into their indicated learning content. Through changing the values of properties of this content, authors can manage the learning resources according to users' requirements. For example, authors can dynamically change the operation rights to these objects, or reorganize the orders of them. Additionally, this system supports some widely-adopted standards (IEEE LOM and IMS Metadata), which makes sure that the created learning content can be easily used by existing e-learning systems.

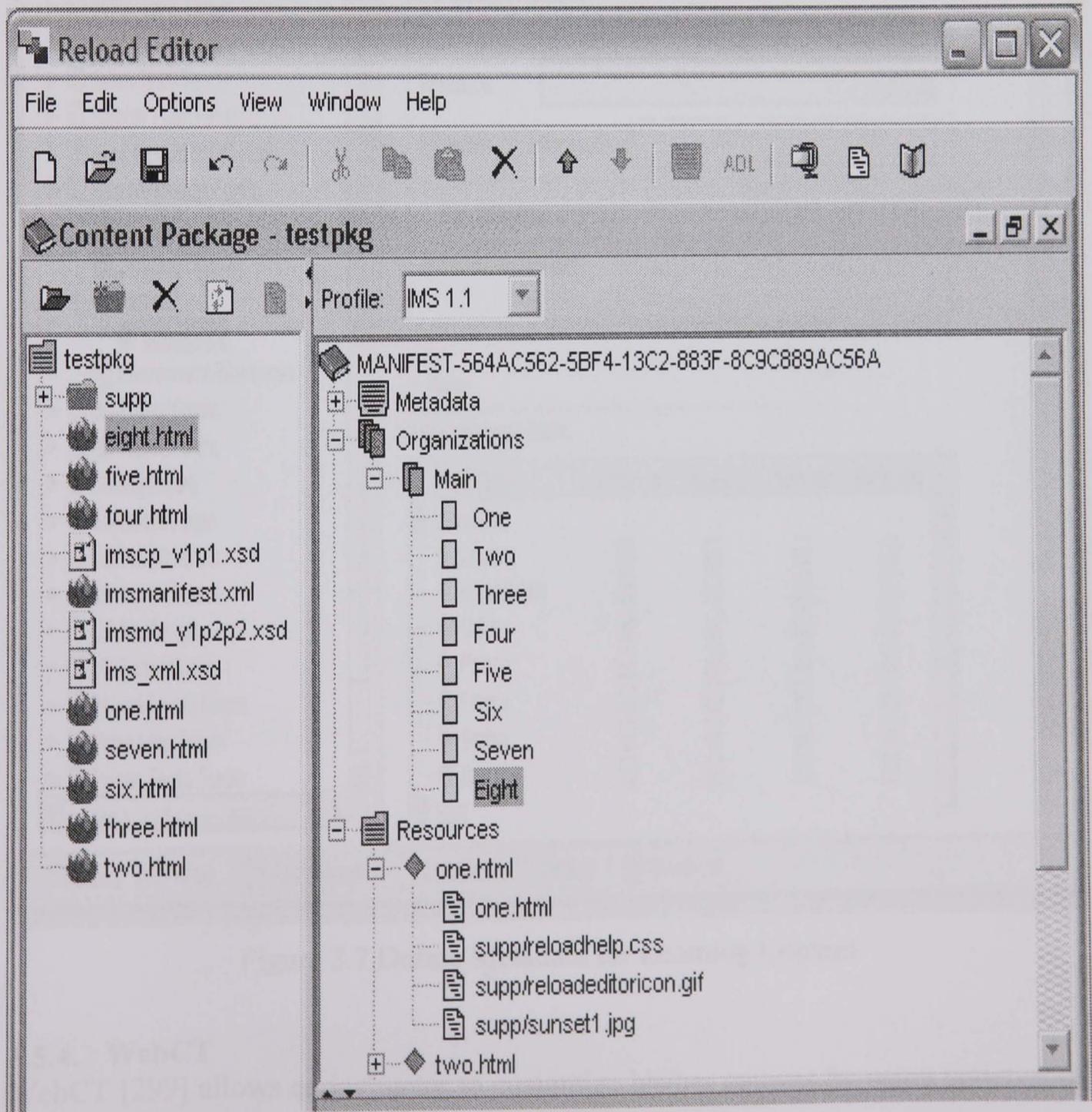


Figure 3.6 Find and Add Learning Content

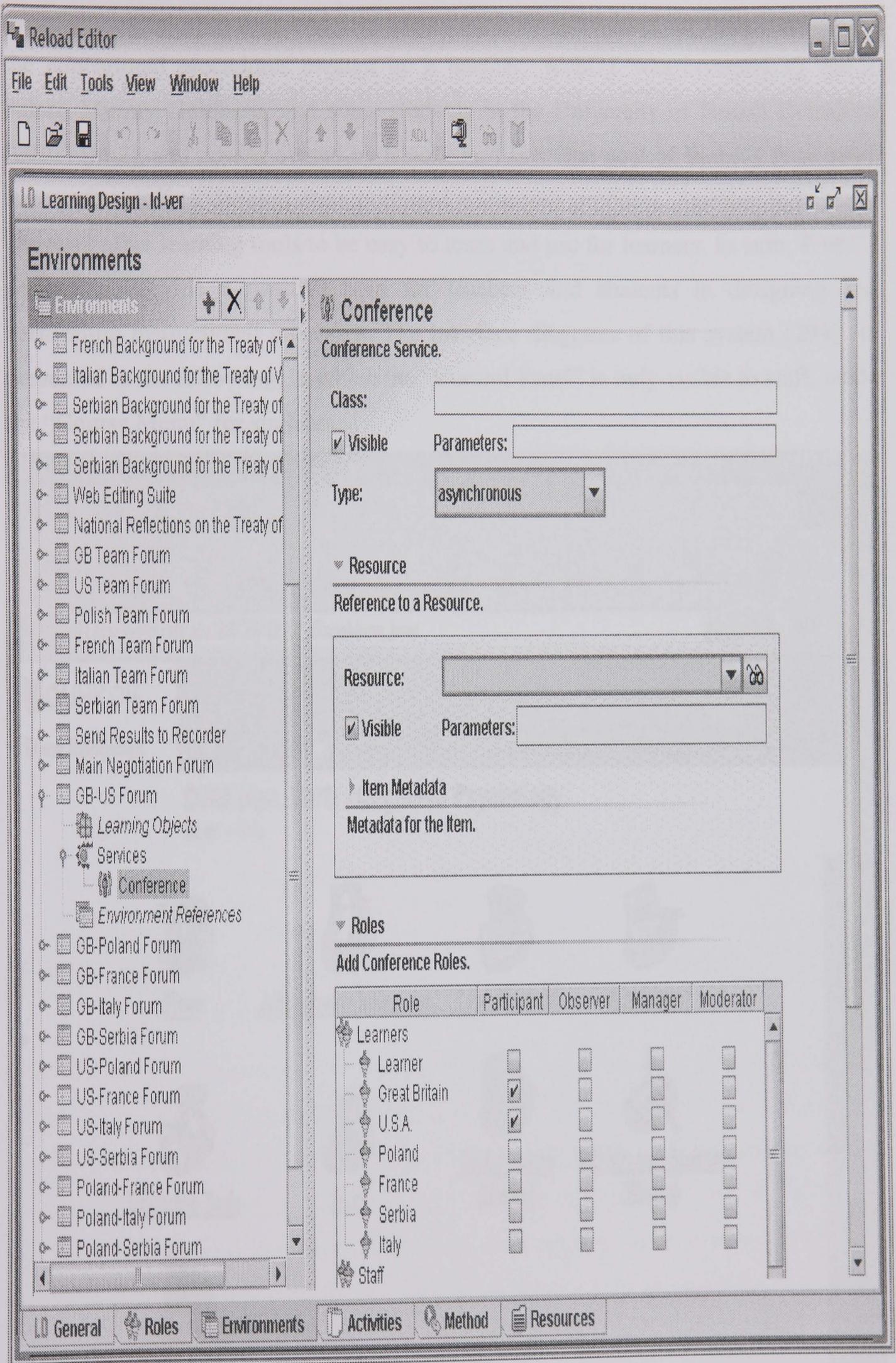


Figure 3.7 Define Metadata for Learning Content

### 3.5.4. WebCT

WebCT [299] allows an instructor to customize his/her courses by using varieties of building blocks such as discussion area, bulletin board, chat room, Web-based

materials, online quizzing, and assessment tool. Students may do their learning on the educational procedures created by a teacher. WebCT was invented by Sasan Salari, Murray Goldberg, and some students in the University of British Columbia (UBC) [302], and now is owned by Blackboard Inc. One goal of WebCT is to make it easy for staff to develop their preferred e-learning products. Another is to make various online learning tools to be easy to learn and use for learners. In sum, WebCT wishes to provide a positive help for teachers and students in designing and performing instructional processes. The interface diagrams of this system [299] are presented in the following, in which the “Control Panel” is only visible to staff, while the “Course Menu” for students.

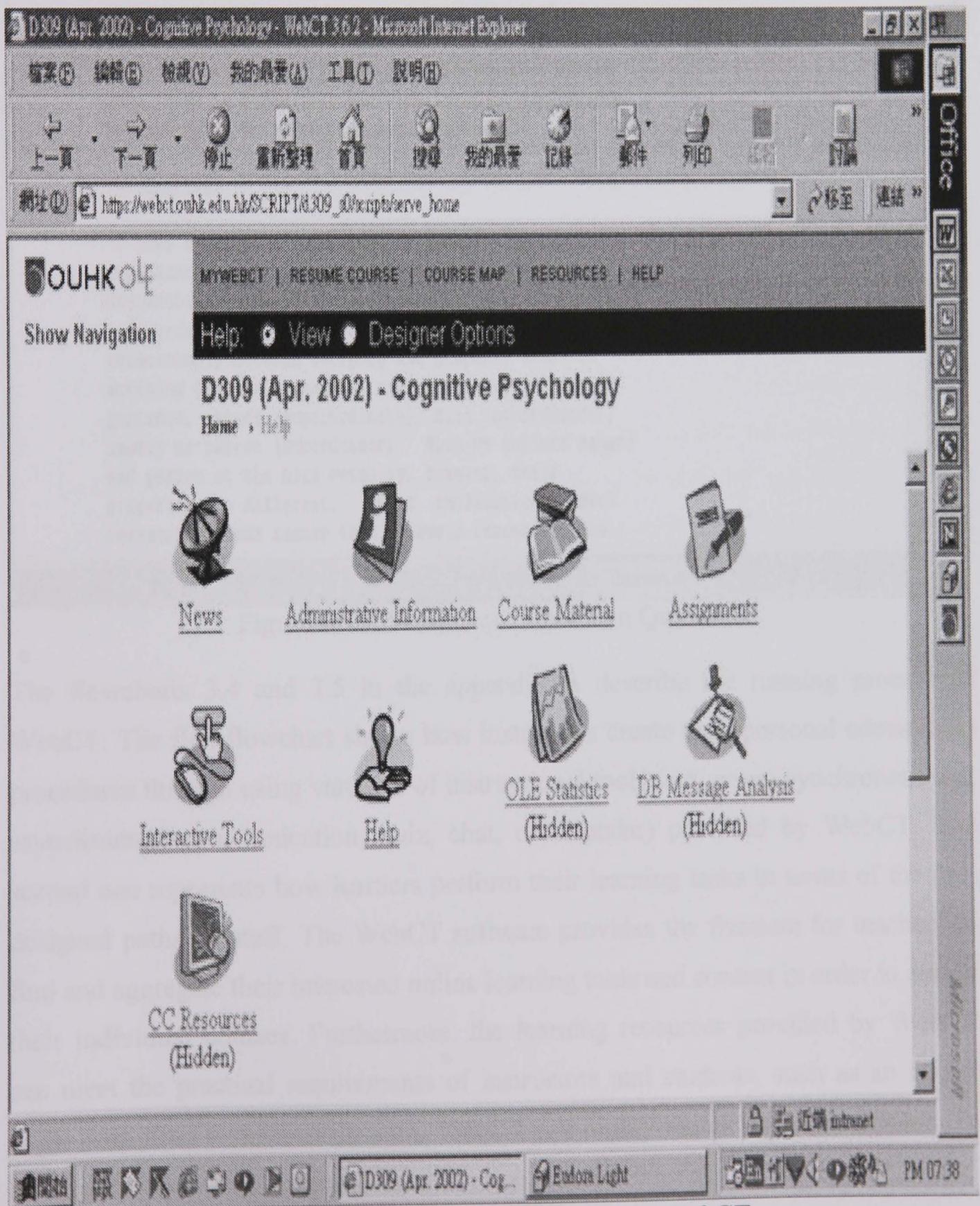


Figure 3.8 Main Page of a Course in WebCT

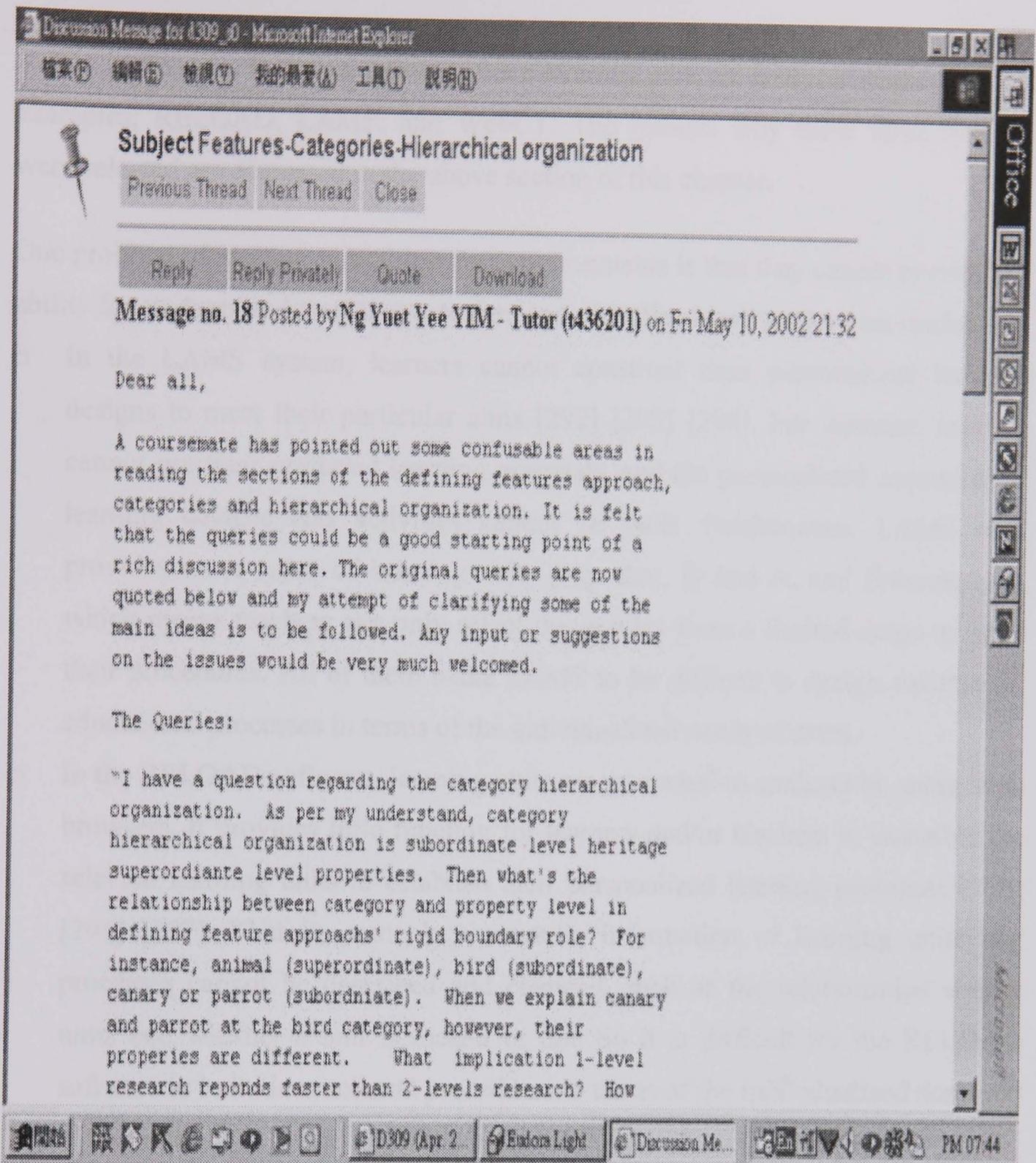


Figure 3.9 A Sample of Discussion Questions

The flowcharts 3.4 and 3.5 in the appendix A describe the running process of WebCT. The first flowchart shows how instructors create their personal educational procedures through using varieties of instructional tools (e.g. group synchronous and asynchronous communication, quiz, chat, or calendar) provided by WebCT. The second one represents how learners perform their learning tasks in terms of the pre-designed paths by staff. The WebCT software provides the freedom for teachers to find and aggregate their interested online learning tools and content in order to author their individual courses. Furthermore, the learning resources provided by WebCT can meet the practical requirements of instructors and students, such as an online exam with time restriction. In sum, WebCT can highly match with the demands in the usability of e-learning systems.

### **3.6. The Technical Research Problems**

In this section, the technical issues in the e-learning area are analyzed based on three examples: RELOAD, LAMS, and WebCT. The reasons why these three systems were selected are discussed in the above section of this chapter.

One problem of existing virtual learning environments is that they cannot provide the ability for students and staff to create their individualized instructional processes.

- In the LAMS system, learners cannot construct their personalized learning designs to meet their particular aims [292] [293] [294]. For instance, learners cannot use their preferred learning materials, and the personalized sequences of learning designs and activities cannot be built. Furthermore, LAMS only provides some types of learning units (e.g. chat, Q and A, and Presentation), which means teachers can only select the options from a limited range to build their procedures. All of them make LAMS to be difficult to design varieties of educational processes in terms of the individualized needs of users.
- In the RELOAD software, learning units are presented to students by using Web browsers. It provides little function for learners and/or teachers to assemble the selected learning units to establish their personalized learning processes [295] [296] [297]. That is, some key semantic information of learning units and processes cannot be described and changed, such as the relationships among units and whether a unit is locked or not. So it is difficult for the RELOAD software to build instructional procedures in terms of the individualized demands in education.
- WebCT lacks the ability to implement the individualized creation of learning procedures by staff, learners, or staff and learners [288] [298] [299]. An example of this is that WebCT only allows instructors to create education processes. In addition, these procedures can only be performed under linear relationship, which can not meet varieties of needs of users such as conditional relationship.

Another issue of existing virtual learning environments is that they cannot provide the ability for students and staff to individually control their performances during the execution of e-learning Web services and applications. For example, a learner is running his or her personalized e-learning Web service. According to the learning results, the student may discuss with the teacher about the next steps of learning. The RELOAD system authors the learning units and delivers them to users or systems, which cannot support users to coordinate their procedures during execution.

Furthermore, the LAMS system can only provide some simple functions for teachers and learners to manage the procedures, such as tracking and stopping processes. Moreover, in WebCT, during running a learning process, learners can only do the things designed in advance and instructors can only monitor learners' progresses without coordinating this process to meet learners' new requirements. All of these systems cannot support users' individualized operations during the running of instruction, such as going back to any learning unit indicated by teachers.

So far, through studying existing e-learning systems, the technical problems have already been presented to readers. Next, a schema-driven approach will be created based on the Semantic Web concepts, which are proposed to solve these issues.

## ***Chapter 4 A Schema-Driven Approach Using Semantic Web Concepts***

This chapter shows a schema-driven approach based on the Semantic Web concepts, which is used to solve the technical problems in this research. It includes six sections. The first section gives a scientific definition of schema and schema-driven approach, and the details of the difference between schema and ontology based approaches. The second section discusses the reasons to select schema-driven approach. The content of third section is to analyse the values to the research through importing the Semantic Web. The fourth section presents the issues of existing Semantic Web approaches. The fifth section represents a schema-driven approach. The final section discusses the application of this approach in the e-learning area at the theoretical level.

#### **4.1. Definitions**

A schema is a machine-readable individualized instance of educational process, in which ontologies are integrated and managed in terms of the practical requirements of users [286] [294]. The main feature of schema technology is that a schema could be a personalized aggregation of the ontologies indicated by users.

The schema-driven approach refers to a flexible process-control mechanism based on the Semantic Web concepts [212]. The aim of this method is to support users to implement the Web-based flexible management of the selected ontologies according to users' needs, such as replacing ontologies, and designing and changing the relationships among ontologies.

Here, we provide an example of the schema-driven approach in the e-learning area. At first, varieties of learning units could be represented as all kinds of ontologies according to the personal demands of learners and teachers [202]. Next according to the needs of users, various schemas could be built through integrating the selected ontologies [292]. Then after the compiling of schemas, various teaching and learning processes could be presented to users on the Web. Also during the execution of learning procedures, the ontologies in these schemas could be controlled in terms of the changes of the circumstances of learners and teachers, such as replacing the next units.

In this research, the relationship between schemas and ontologies was summarized. Ontologies are regarded as a set of controlled collections of concepts, which consist of machine-processable semantics [303]. The difference between schemas and ontologies is that a schema is used to aggregate and manage the indicated ontologies in terms of a user's requirements or the consistent demands of users. In detail, in order to complete different tasks, users may select different ontologies and design the individualized orders among these items to build their special schemas.

#### **4.2. The Deriving of Schema-Driven Approach**

The aim of this research is to support a range of teaching styles. Through investigating the tools of LAMS, RELOAD, and WebCT, we found it is possible to accomplish the research objective by improving the approaches used in them. In order to solve the research problems, the key point could be the supporting of the personalized creation and management of learning processes. The methods used in the three systems present the ability to author and control learning units and

processes with metadata techniques. So through integrating and increasing the functions of these methods, the practical questions will be solved. The schema-driven approach used in this thesis is mainly designed based on these methods. Furthermore, there could be some other ways in the e-learning area to deal with the research problems. As this research focuses on meeting the actual requirements of users, so the work is to use a way to complete this aim not to try every road.

The main values for using the schema-driven approach in this research are discussed in the section 4.6.2..

### **4.3. Why Select the Semantic Web**

Learners and teachers may hope to design and complete teaching and learning tasks in terms of their individualized requirements (Chapter 2). It means that virtual learning environments need to provide the functions for users to support their various personal demands, such as selecting different teaching styles and units, and designing all kinds of learning processes. So far, existing virtual learning environments have mainly focused on creating, publishing, delivering, and simply managing learning units on the web (section 3.6. of Chapter 3). They can not meet the needs such as the individualized creation of educational procedures. The Semantic Web (section 3.3. of Chapter 3) could be a potential way for the authoring and management of personalized e-learning Web services and applications [304]. It could efficiently describe the semantic information of learning units and processes and greatly facilitate users to manage the information. This allows learners and teachers to meet their personalized teaching and learning requirements more easily. In this research, we propose to import the Semantic Web concepts into our schema-driven approach.

In detail, the main values of combining the Semantic Web with e-learning are described as follows:

- The Semantic Web could provide the ability for students and staff to make efficient representation of e-learning Web services and applications [305]. The Semantic Web technologies (e.g. metadata, ontology and markup languages) could be used to build the models of subjects in terms of the knowledge that the subject consists of [306]. In the e-learning area, the technologies of Semantic Web could describe specific information of learning units and processes according to users' addressing subjects (e.g. learning objectives, topics, and/or skills) [307]. For example, the semantics (e.g. titles and content) of learning units

required by a learner could be represented in terms of his/her learning aims. Also other required properties of learning units and processes could be flexibly set up, such as what they do, how they should be used, and who can use them.

- The Semantic Web could largely facilitate learners and teachers to manage their personalized e-learning Web services and applications [308]. The RDF, XML, and OWL used in the Semantic Web could support machine-readable descriptions of learning units and processes [309]. So it could support users to easily composite, publish, discovery, select, share, retrieval, reuse, invoke, and combine teaching and learning information [310]. Also the semantic information of learning units and processes could be easily exchanged on the Web. Furthermore, varieties of semantics of learning units and processes could be changed in terms of the individualized needs of users [311]. In sum, the requirements of teachers and learners could be understood and executed by computers in order to produce users' interesting e-learning Web services and applications.

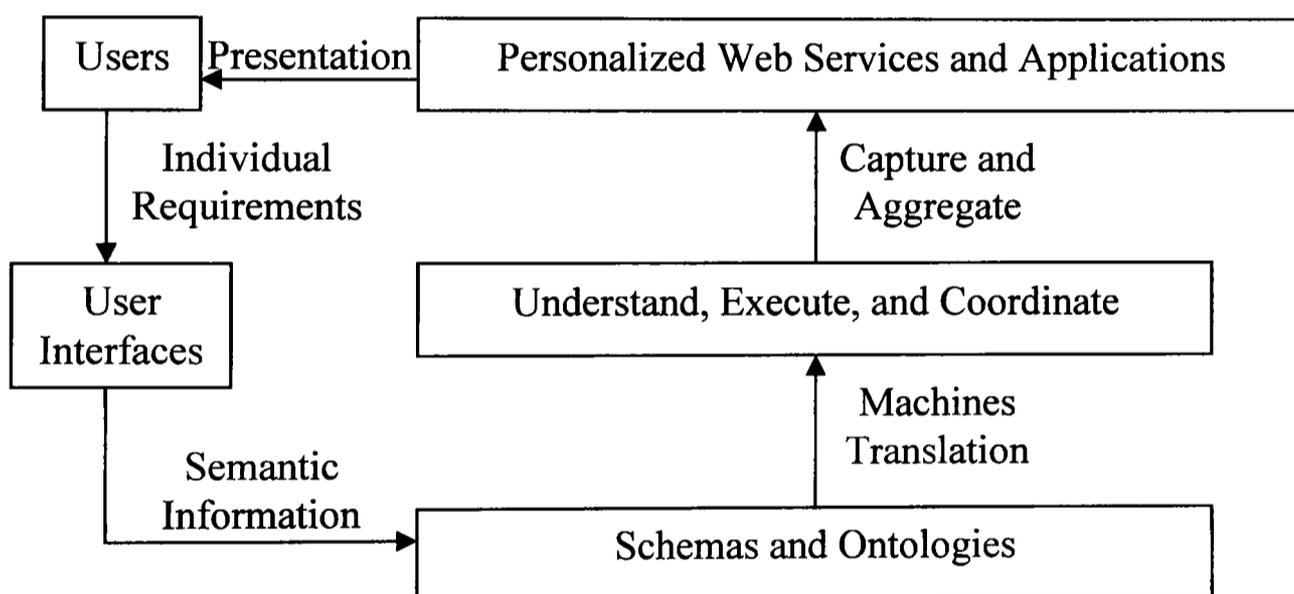


Figure 4.1 Relationships between the Building Blocks

The above diagram shows the building blocks of the Semantic Web concepts used in this thesis: Personalized Web Services and Applications; Understand, Execute, and Coordinate; Schemas and Ontologies. The semantics of Web services and applications (e.g. e-learning Web services) described based on users' demands could be used to design individualized schemas and ontologies in which the information are machine-readable. Next, computers could capture and aggregate the required items (e.g. learning units) according to the semantics in schemas and ontologies. Then, the preferred Web services and applications (e.g. learning processes) would be presented to users and be executed on the Web. Finally, during running these services and applications, the semantic information in schemas and ontologies could be

changed in terms of the needs of users. It means that the practical Web services and applications could be coordinated to meet users' personal demands.

#### **4.4. Why not Use Existing Approaches in the Semantic Web**

The main problems of existing Semantic Web approaches (e.g. IRS-III and OWL-S, section 3.3.1. of Chapter 3) can be described as follows:

- Existing Semantic Web approaches cannot support varieties of models of a type of Web services and applications. For each kind of Web service and application, there are a set of models to simulate it based on different aims and approaches [312] [313]. For example, in the e-learning area, there are various teaching and learning patterns [6]. These manners will be selected by students and staff in terms of learners' personal background knowledge, learning abilities, aims, content, and roads. So it is very important to provide the ability for users to build and execute their preferred learning models mapping to the chosen manners. Existing Semantic Web approaches mainly describe the semantic information of objects and processes [314] [315]. They do not provide a mechanism for users to establish various instructional models [316].
- Existing Semantic Web approaches can not support the personalized control of users' performances in Web services and applications. When humans performing their individualized Web services and applications, there could be a lot of new behaviours that are not early planned [317] [318]. For example, when executing instructional procedures, through analysis of students' learning results, some learners and teachers may wish to change their processes, such as setting new orders between learning units [319]. So it is necessary to provide a method for users to control their teaching and learning procedures during execution. The main functions of existing Semantic Web approaches are the composition, publishing, discovery, selection, sharing, and reuse of semantic information [314] [315]. They do not provide the management capacity for learners and teachers to control their educational processes according to the changes of their circumstances [316].

#### **4.5. A Schema-Driven Approach**

In order to deal with the problems discussed in Chapter 3, we propose a schema-driven approach to design a flexible virtual learning environment.

#### 4.5.1. Ontology and Metadata

In this research, there are two types of ontology: vocabulary [320] and term [321]. Also metadata comprises a set of data elements [322]. The details of these ontologies and metadata can be described in the following paragraphs.

**Vocabulary:** A vocabulary is a collection of some terms and data elements, which is used to contain the structure and semantic information of a collection of learning units. According to the demands of users, a vocabulary can be composed of different terms and data elements. A vocabulary could be a part of a schema, which can be created, changed, and replaced by learners and teachers in terms of their personalized needs.

For example, a vocabulary is used to describe a collection of learning units, which contains three objects: a HTML file, a picture, and a Word document. It means that this vocabulary also has three terms that are used to represent the structure and semantic information of these three units. In addition, the data elements in this vocabulary are used to describe the structure and semantic information of this collection, such as the title and version number of this vocabulary, the relationships between this vocabulary and other vocabularies in a schema, the relationships between this vocabulary and its terms, and the technique properties of this vocabulary.

**Term:** A term is a collection of some data elements, which is used to contain the structure and semantic information of a learning unit. In order to describe different learning units, terms may consist of different data elements. A term is an integral part of a vocabulary, which can be created, changed, and replaced by users according to their requirements. The data elements in a term are used to describe the structure and semantic information of this term, such as the name and version number of this term, and the relationships between this term and other terms in a vocabulary or a schema.

For instance, a term is used to represent a learning unit: a Web page. Some data elements are chosen by users to compose this term, which are used to describe the structure and semantic information of this object, such as the address of this file, the limitation in operations to this file (e.g. read-only or some users can not open this file), and the relationships between this file and other learning units.

**Data Element:** A data element is used to define a type of semantic information of a learning unit or process, such as the title and version number of a process, the relationships between one unit and others. In this research, the data elements are defined based on the practical requirements of users and the standards such as UK LOM Core and IEEE LOM. According to different using areas (e.g. e-learning and electronic business), different data elements could be created to describe different units and processes such as business processes.

#### 4.5.2. The Structure of Schemas

In a schema-driven approach, schemas are composed of three components: vocabularies, terms, and data elements. These components can describe the structure and semantic information of learning units and processes according to users' demands, and make the structure of schemas modular. The following diagram shows the structure of schemas in this research.

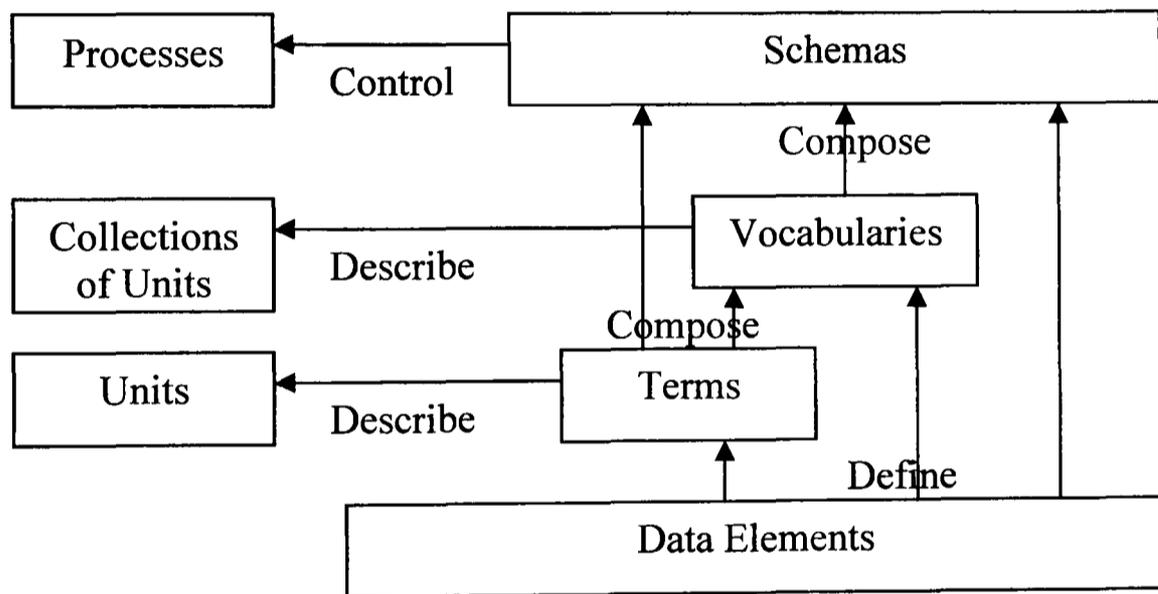


Figure 4.2 The Structure of Schemas

At first, users can select some data elements to create personal terms and vocabularies according to their individualized requirements. In detail, the data elements of a term can describe the name and version number of this term, and the relationships between this term and other terms in a schema or a vocabulary. Next, a schema is composed of a set of data elements and vocabularies or terms in terms of users' needs. Users can aggregate these vocabularies and terms based on their particular orders in a schema. Also the data elements of a schema can represent the name and version number of this schema, and the names and version numbers of vocabularies or terms in this schema. Furthermore, the values of the data elements in a schema, vocabulary, and term can be changed to meet users' demands. Thus the schema-driven approach can support users to design and control various schemas to

represent all kinds of processes of Web services in terms of personalized requirements of users.

#### **4.5.3. BNF Definitions of Schema, Ontology, and Metadata**

The BNF definitions [323] of schema and metadata: vocabulary, term and data element can be described as follows:

$$\text{Schema} ::= \text{Vocabulary} \{ \text{Vocabulary} \} \mid \text{Term} \{ \text{Term} \}$$
$$\text{Data Element} \{ \text{Data Element} \};$$
$$\text{Vocabulary} ::= \text{Term} \{ \text{Term} \}$$
$$\text{Data Element} \{ \text{Data Element} \};$$
$$\text{Term} ::= \text{Data Element} \{ \text{Data Element} \};$$

This summarized description presents the relationships among schema, vocabulary, term, and data element. The details about the BNF composing of schema, ontology, and metadata are shown in Appendix B.

#### **4.5.4. The Features of Approach**

The main features of the schema-driven approach used to deal with the technical issues in this research can be described as follows:

One feature of this approach is that it could provide the ability for users to describe the required structure and semantic information of units and processes, such as learning units and processes. All kinds of data elements could be designed to describe the information required by users, such as the name, address, and version number of a unit or process, and the relationships among units in a process. Furthermore, individualized terms are composed of various semantic information that users need to achieve their personal aims. Finally, individualized schemas could be authored by assembling the indicated terms and data elements according to the orders and conditions designed by users. All of them show that this approach could contain and aggregate the semantic information of the processes and units which are built based on the practical demands of users.

Another feature of this approach is that it could support users to flexibly control the processes during their execution in terms of their personalized requirements through changing the values of data elements. The needs of users could be different before and during they perform their procedures as the circumstances of users could be changed (section 2.4. of Chapter 2). Also it is difficult for users to pre design every

thing in their procedures. Thus it is crucial to provide the ability for users to coordinate their processes according to their demands. This approach designs a set of properties in schemas, vocabularies, and terms, which could be used to control the directions of procedures (Chapter 5).

#### **4.6. The Theoretical Representation of Approach in E-Learning**

In this section, we present a description of the usage of the schema-driven approach in the e-learning area. This approach could provide the ability for learners and teachers to drive and control individualized performances in e-learning Web services and applications.

##### **4.6.1. The System Flowcharts**

The flowcharts 4.1 and 4.2 in the appendix A describe a flexible virtual learning environment based on schema-driven approach, which are drawn for two roles: tutor and tutee. These diagrams describe how to support learners and/or teachers to create special learning procedures with the complex relationships among the indicated units based on schemas, ontologies, and metadata. Also they present how to use schemas to control the personalized performances of users in their instruction. The detailed information about these functions will be discussed in Chapter 5.

##### **4.6.2. The Achievements by Using the Approach**

As shown in the flowcharts 4.1 and 4.2, the new schema-driven approach could support users to assemble the semantic information of learning units and processes, and manage their individual operations during doing their education. The main value of this method is that it could provide the ability for teachers and learners to perform their individualized teaching styles on the Web. The details of these achievements have been discussed in Chapters 5 and 6.

This chapter provided a high-level view of a schema-driven approach. Next, this method will be shown to readers from the point of technique design.

## ***Chapter 5 Design a Schema-Driven Approach***

In this chapter, we give the technical representation of schema-driven methodology. It consists of five sections. The first section introduces the framework of the approach. The second section shows a key building block in this method: a schema-driven management system including architecture, working processes analysis, and features. The third section describes the architecture, analysis, and characteristics of a schema-driven distributed database management system. The fourth section discusses the databases of schema, ontology, and metadata. The final section presents a concrete description of the usage of this approach in the e-learning area.

### 5.1. The Technical Framework of Approach

The following diagram shows the modules of a schema-driven approach, which comprises three building blocks, application programming interfaces (APIs) [324], and user interfaces (UIs) [325]. These modules can be described as follows:

*A Schema-Driven Management System* is the core building block of a schema-driven approach. Through creating, changing and replacing vocabularies, terms, and data elements, it could provide the ability for users to create personalized schemas and to flexibly control these schemas during their execution.

*A Schema-Driven Distributed Database Management System* is driven and controlled by schemas, which is responsible for the maintenance and management of schemas, vocabularies, terms, and data elements in databases, such as searching and returning the required items to a schema-driven management system.

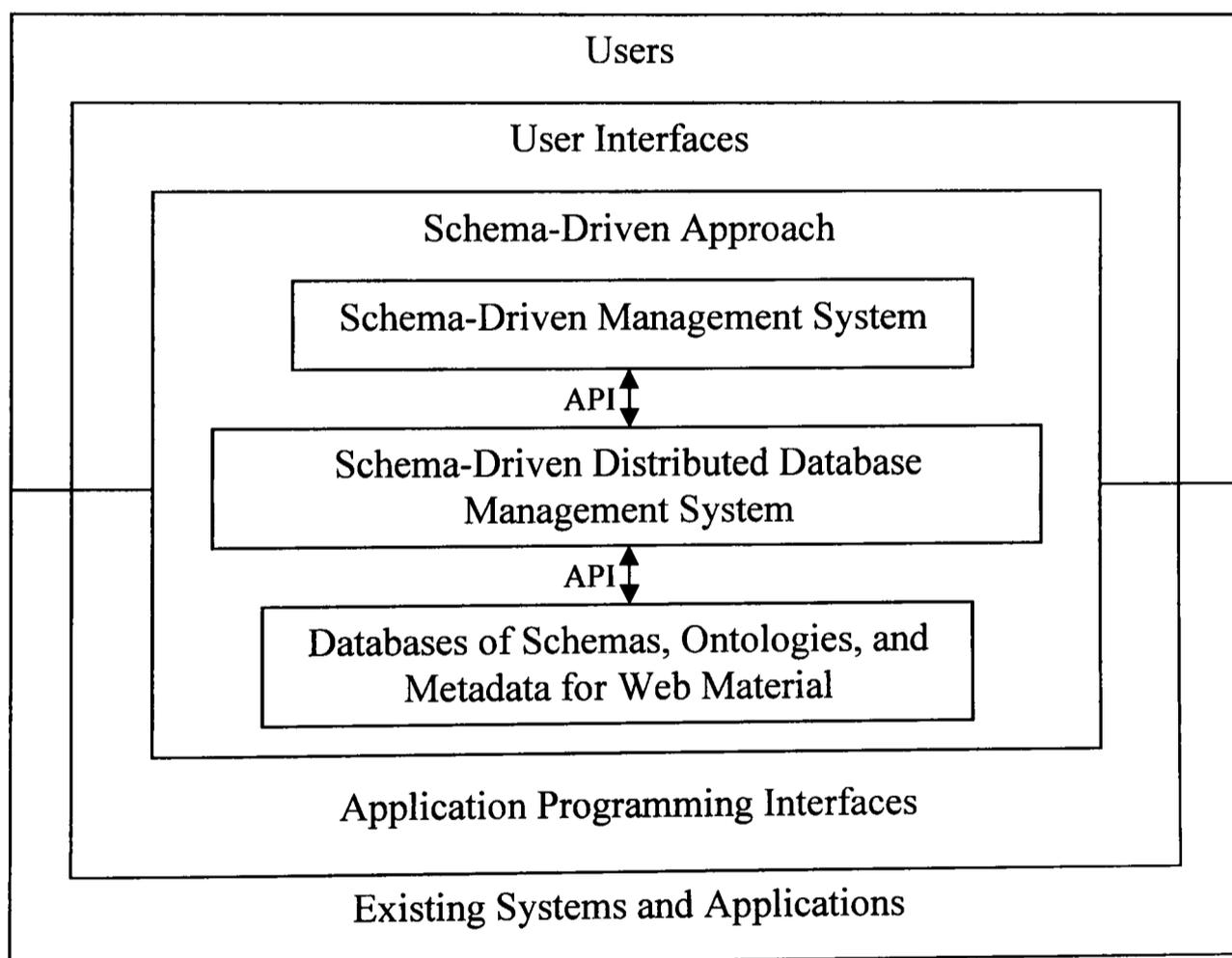


Figure 5.1 The Architecture of Schema-Driven Approach

*User Interfaces (UIs)* are a set of dialog boxes presented to users, which could support the communication between users and a schema-driven management system.

*Application Programming Interfaces (APIs)* are the packages of programs to transfer schemas, vocabularies, terms, and data elements among the building blocks. One API is used to deliver items between a schema-driven management system and a schema-

driven distributed database management system. Another API is used to transfer items between a schema-driven distributed database management system and the databases of schemas, ontologies, and metadata.

*Databases of schemas, ontologies, and metadata* are a set of relational repositories to store schemas, vocabularies, terms, and data elements, which are distributed on the Web.

Here we present the working process of this framework. At first, users input their personalized semantic information through user interfaces and deliver these information to a schema-driven management system. Next the semantics provided by learners and teachers are used to build the required terms and other items by this schema-driven management system. By using application programming interfaces, the creations are transferred to a schema-driven distributed database management system, and are stored into the databases of schemas, ontologies, and metadata. Meanwhile, the created schemas are presented to users as the required processes to meet users' various individual demands, such as their interested orders of units. During the running of processes, the schema-driven management system could coordinate these processes in terms of the changes of users' needs.

## **5.2. A Schema-Driven Management System**

A schema-driven management system takes charge of creating and manipulating schemas, vocabularies, and terms in order to support users' personalized performances to units and processes.

### **5.2.1. The Modular Diagram of this System**

In this section, we analyze the functions of the main components in a schema-driven management system. The details are discussed as follows:

*A Schema Processor* [326] is an ontologies aggregation and control mechanism that is responsible for the implementation of individualized operations to units and processes. In a schema processor, a generation application of term, vocabulary, and schema is used to capture the values of data elements input by users. Next this application automatically assembles the semantic information to create the required items and presents them to users.

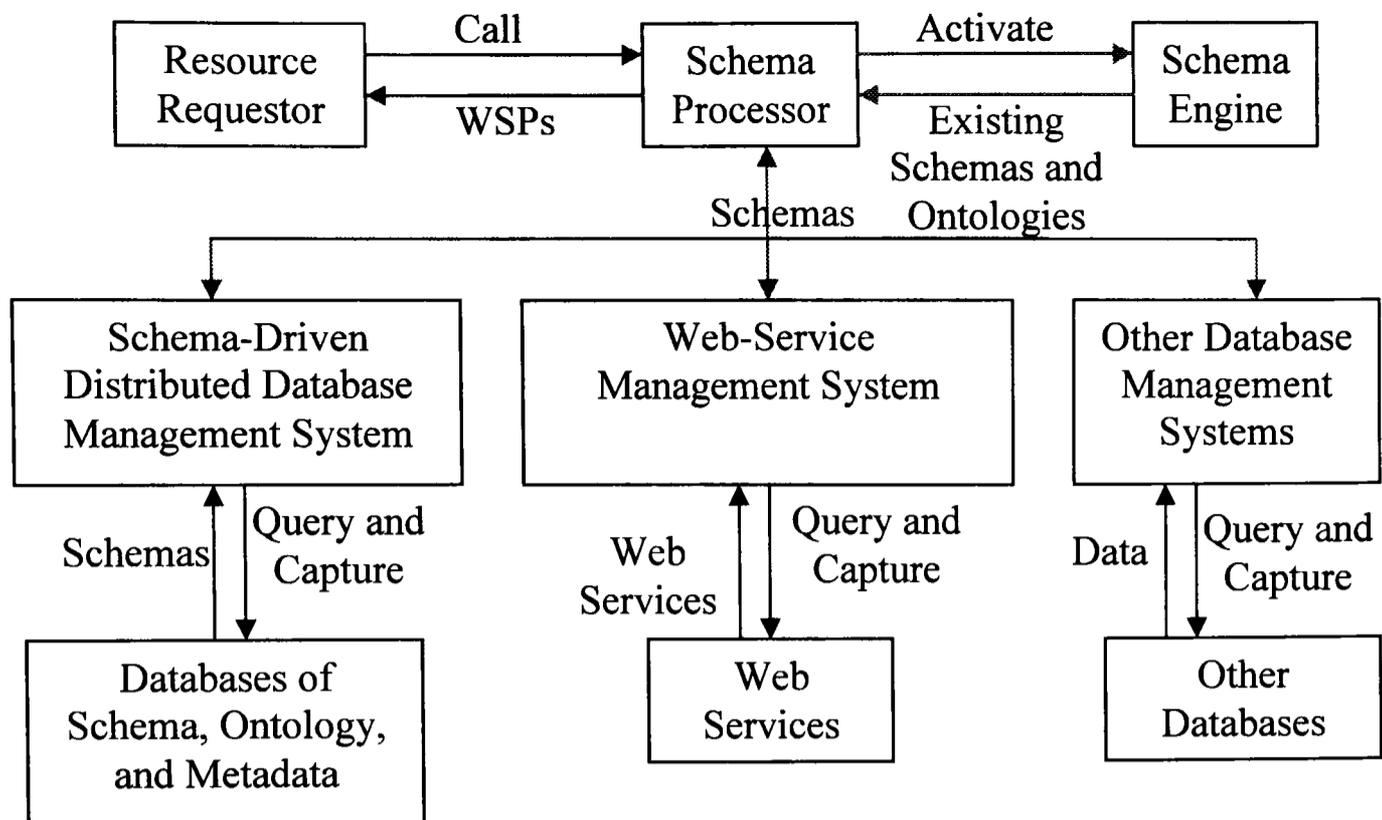


Figure 5.2 The Modular Diagram of Schema-Driven Management System

Notes: A WSP (*Web Services Package*) [327] is designed based on WSDL, SOAP, and UDDI, which contains the semantic information about Web services or applications required by users, such as a learning unit and process.

A *Schema-Driven Distributed Database Management System* is designed to manage data in the databases of schema, ontology, and metadata. It is driven and controlled by a schema processor and could store, search, add, delete, and modify items.

A *Schema Engine* is a module activated by a schema processor to search, locate, and trigger existing schemas and ontologies, and deliver them to schema processors deployed on the Web.

A *Web-Services Management System* [327] is built based on the Web-services architecture from W3C metadata technology and Sun ONE architecture [328], which is composed of three key architectural components: Role, Web service, and business process. Through using this system, a schema processor could provide the interesting Web resources to users, such as opening a Web page or a Word document.

*Web Services* are a set of services which can be implemented individually or in batches on the Web, such as an interface to facilitate users, systems, or applications to access a specific or group of functions or data sources.

*Resource Requestor* can be a user, a client application, an application running on a computer, or any Java enabled client, which requests data and services on the Internet. In this thesis, the term “resource” refers to learning units and processes.

*Other Database Management Systems* are existing systems for data management, such as relational and object-oriented database management systems, which can support the communication by using the JDBC [329] or ODBC [330] technology.

*Other Databases* refers to existing databases accessed via JDBC or ODBC and deployed on the Web.

### **5.2.2. Analysis of this System**

This system carries out nine behaviours (subsystems) of a schema-driven approach: receive requirements, require data, receive data, change the values of data elements, create and change ontologies, create and change schemas, design relation, drive and control personalized operations to units and processes, and manipulate feedback. The functions of this system are shown in the following use case diagram.

Through performing the behaviour “receive requirements”, this schema-driven management system could get the demands from users at any time. Next the system could activate the “require data” to communicate with a schema-driven distributed database management system to capture the required items and return them to the “receive data”.

Then the schema-driven management system may automatically complete a set of operations according to the requirements of users or applications. For example, the “change the values of data elements” module could modify the content of data elements in every term, vocabulary, and schema. The application “create and change ontologies” could generate new terms and vocabularies based on these data elements, and store them by using a schema-driven distributed database management system. Furthermore, the behaviour “create and change schemas” could aggregate the selected terms or vocabularies to author individualized schemas. If the relationships among terms or vocabularies need to be built or changed, “design relation” could be invoked to complete this task.

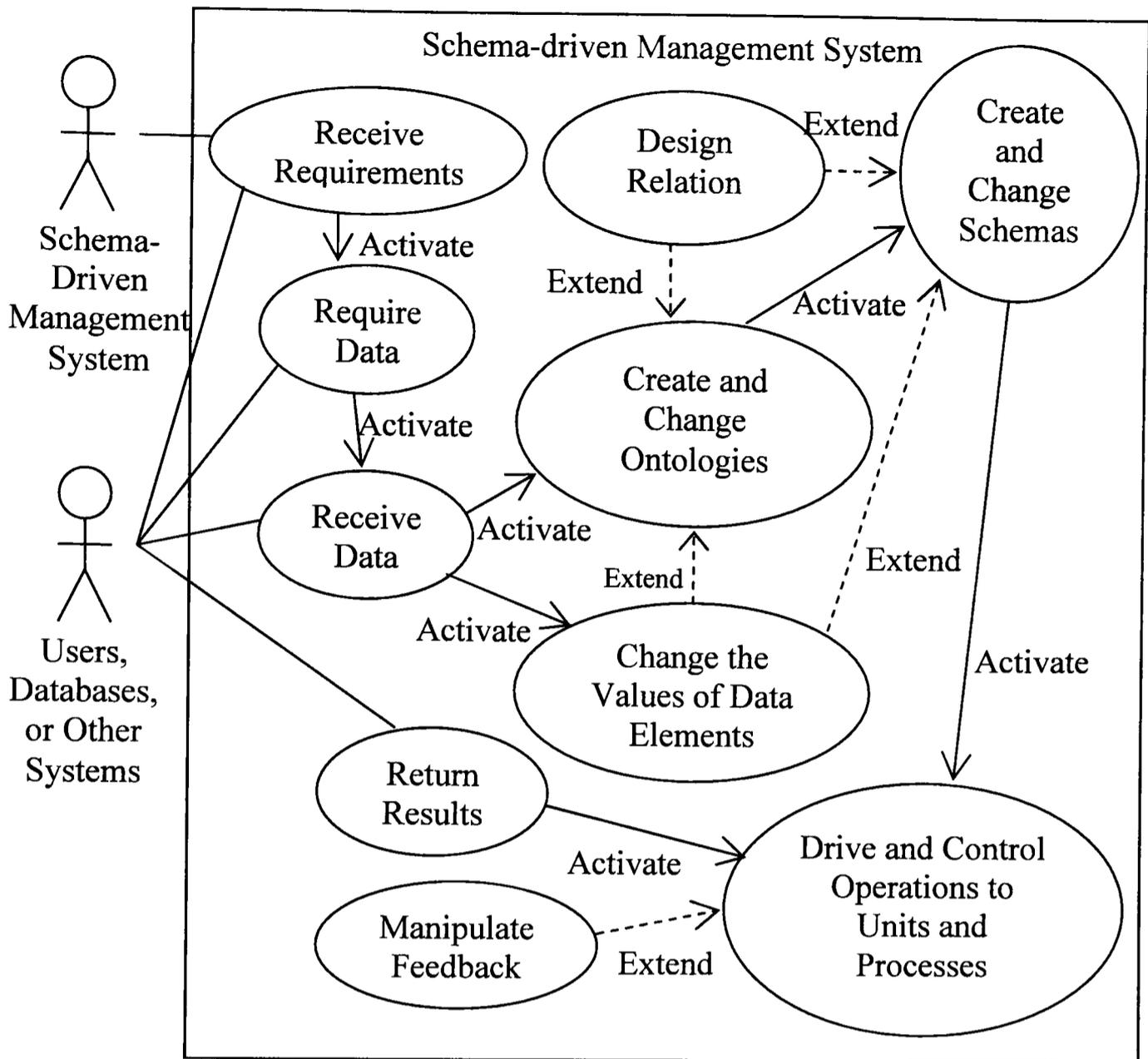


Figure 5.3 A Use Case Diagram of Schema-Driven Management System

Finally, the application “drive and control operations to units and processes” could manage the execution of various processes. In detail, this application could allow users to change the values of data elements in schemas, vocabularies, and terms and do the demanded operations based on these values. For instance, this component could lock a HTML file or other units indicated by teachers and learners, which makes them to be unavailable to learners. Or the application could help students to open the unlocked units in different formats such as Web page and Word. Furthermore, if there are some exceptions returned from the schema-driven management system or other communicated systems, the module of “manipulate feedback” could capture the information and automatically process them, such as deliver the results to users or applications.

### 5.2.3. Features

The main characteristics of schema-driven management system can be described as follows:

- This system could provide a mechanism based on the Semantic Web technologies for users to create personalized schemas, vocabularies, and terms. The detailed information has already been discussed in the section 5.2.2.. The main value of this function is that varieties of learning processes could be built to meet users' individualized orders and conditions as far as possible.
- This system could provide the ability for users to control personalized performances to units and processes during the execution. The above section has completed the detailed analysis of this feature. This function could be very helpful for this research, as the changes of circumstances of users during the running of processes could be supported as much as possible.
- This system could be built on generally accepted standards and protocols, such as XML, WSDL, and IEEE LOM. This feature could facilitate the interaction and communication with other systems or applications, so it has the strong life-force. Furthermore, this system could support widely-used database connection standards such as JDBC and ODBC, which makes it easy for users to access existing relational databases and other databases supporting these protocols on the Web.

### **5.3. A Schema-Driven Distributed Database Management System**

A schema-driven distributed database management system is another key building block of a schema-driven approach, which is responsible for managing data elements and other items in the databases discussed in the section 5.4.. This system is driven and controlled by a schema-driven management system.

#### **5.3.1. The Architecture of this System**

The main components of the system are shown in the following diagram. As some of the components have been analyzed in section 5.2., here we just discuss the others:

*A Core Data Processor* is the core component of a schema-driven distributed database management system. Compared with the schema processor, it is the low-level controller to manipulate data in the databases of schemas, ontologies, and metadata.

*A Database Engine* is used to search, locate, and return the selected data from databases distributed on the Internet.

*A Database Connector Repository* is a collection of APIs such as JDBC and ODBC, which provides bridges to access databases.

*Data Source* is a collection of the databases of schemas, ontologies, and metadata, which can be accessed through JDBC or ODBC.

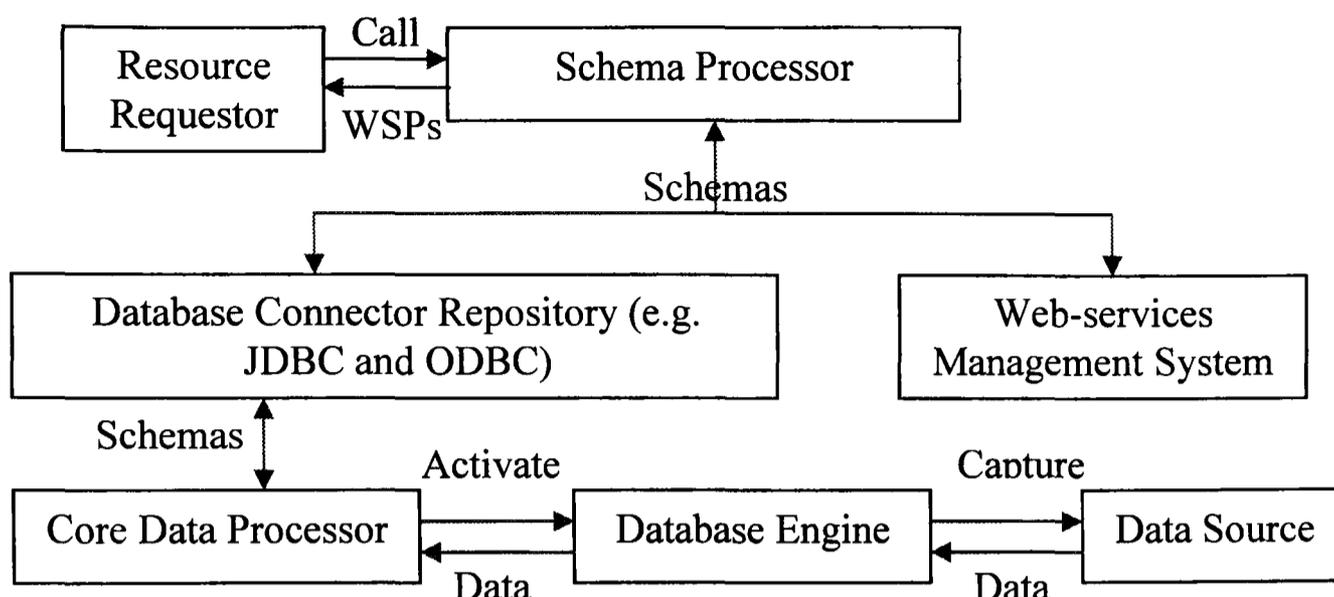


Figure 5.4 The Architecture of Schema-Driven Distributed Database Management System

### 5.3.2. Analysis of this System

In general, this system could perform nine behaviours: receive data, manage data, search data, store data, delete data, change data, return results, concurrent versions management, and digital rights control. A core data processor called “Manage Data” could drive and control other applications. The functions of this system are shown in the following use case diagram.

The application of “receive data” may deliver the information input by users to a core data processor. Next according to these requirements, the core data processor could activate an application “search data” to search for the required data elements, terms, vocabularies, and/or schemas in databases. Then the processor could return the required data to a schema-driven management system by using the module “return results”. Furthermore, the processor could add a new record from users into databases by using the “store data” module. In addition, the application of “change data” could change the address and the date of creation of data. Further, the system of “concurrent versions management” could update the databases on servers and clients and support the concurrency control of learning units and processes. So when data is being written by a user or an application, other performances to the data by other users or applications could be allowed. Finally, the “digital rights control” application could use data elements (e.g. lock and read only) to describe and control the rights of users in performing data, such as who can open this learning unit, and how to use it.

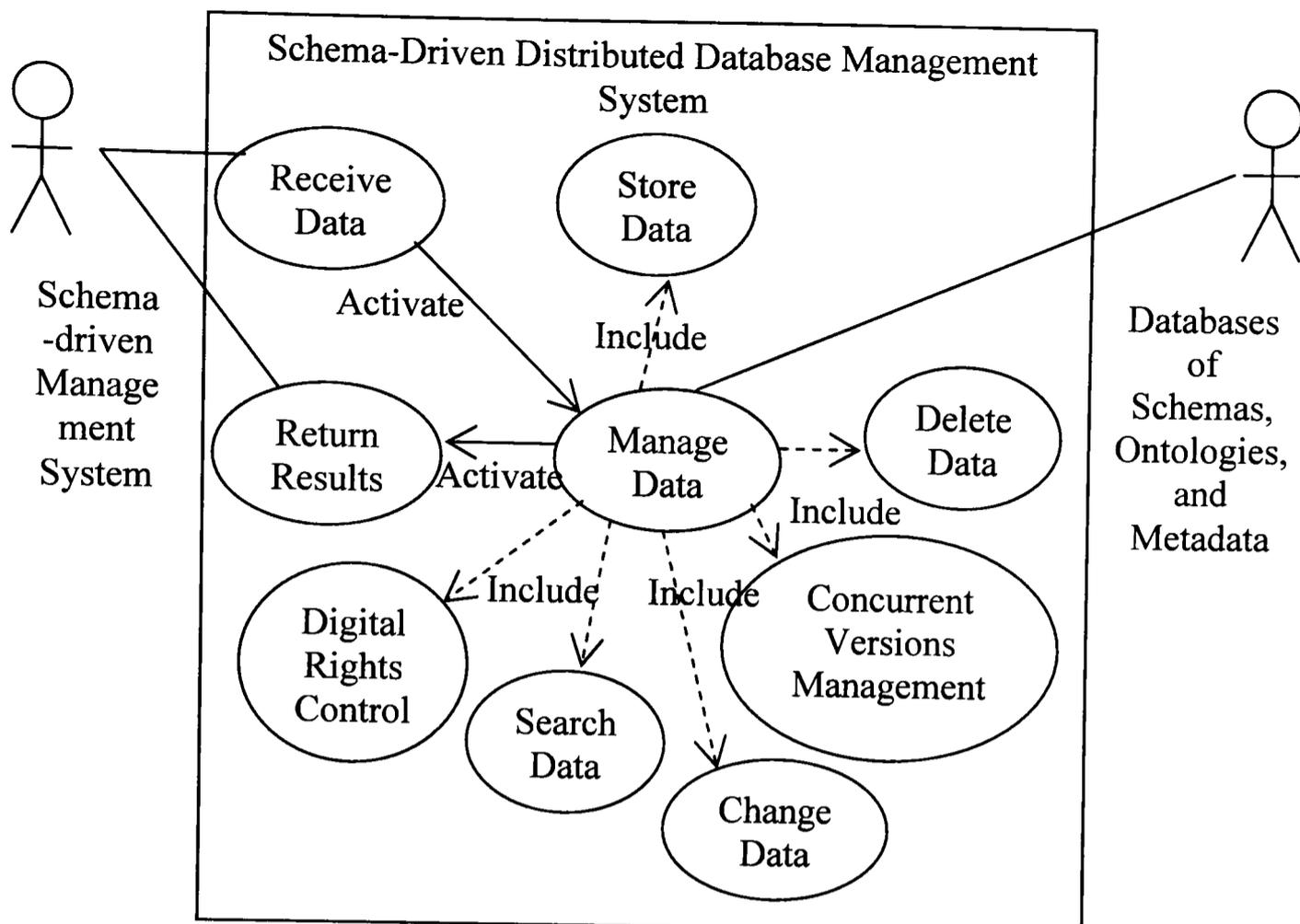


Figure 5.5 A Use Case Diagram of Schema-Driven Distributed Database Management System

### 5.3.3. Features

The characters of a schema-driven distributed database management system can be summarized as follows:

- This system could facilitate the performances to the data in databases through supporting a set of functions discussed above. It could be a strong basis for a schema-driven management system to complete the tasks indicated by users.
- This system could support JDBC and ODBC, which could enable this system to perfectly communicate with existing databases deployed on the Internet.

### 5.4. Databases of Schema, Ontology, and Metadata

A database of schemas, ontologies, and metadata is a basic building block of a schema-driven approach, which is used to store terms and other items. It is a semantic database [331] and deployed on the Web. A semantic database refers to a relational database that can present semantic views of units and processes (e.g. learning units and processes) to users. The data used to describe an object is stored as some reports or tables in a semantic database. Through using semantic schema, SQL, and XML technologies, the semantic information of object is assembled in a schema and delivered to a distributed database management system.

### 5.4.1. Memory Structure

In order to manage the data in databases, we need to build the relationships among our selected components. The figures 5.6 and 5.7 show the relationships among vocabularies or terms, between vocabularies and terms, or between schemas and terms or vocabularies. These relationships are designed based on the structure of schemas (section 4.5.2. of Chapter 4). Administrators of these databases could create and change these relationships through giving the values of data elements (e.g. source version number and target version number) in schemas, vocabularies, or terms.

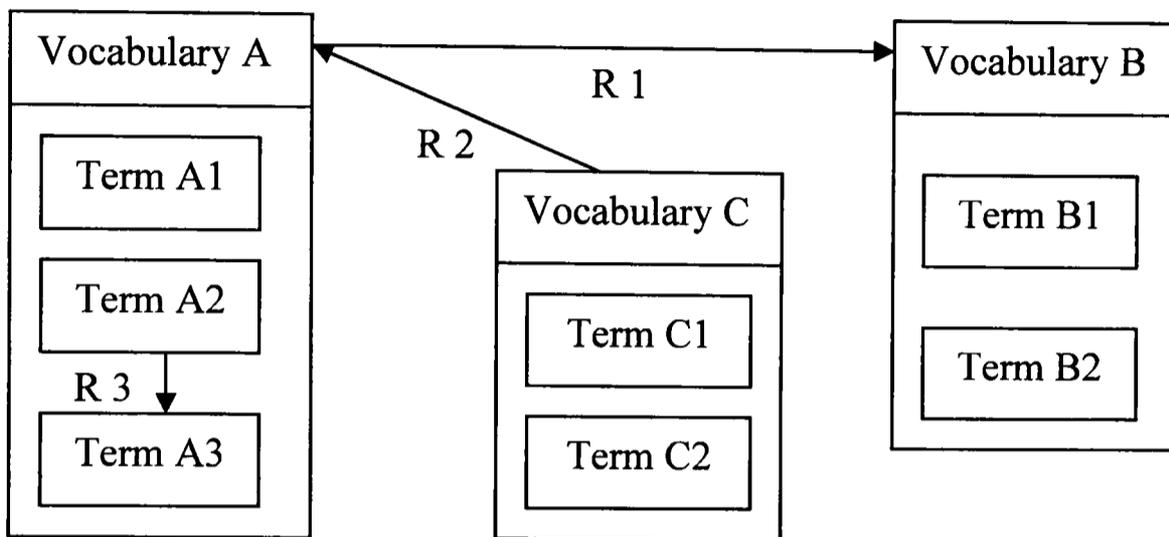


Figure 5.6 The Relationships among Terms or Vocabularies or between Terms and Vocabularies

In the above diagram, the relationships 1 and 2 (R1 and R2) define that vocabulary A is played in front of vocabulary B and behind Vocabulary C, and the R3 relationship indicates that term A2 must be performed before operating term A3.

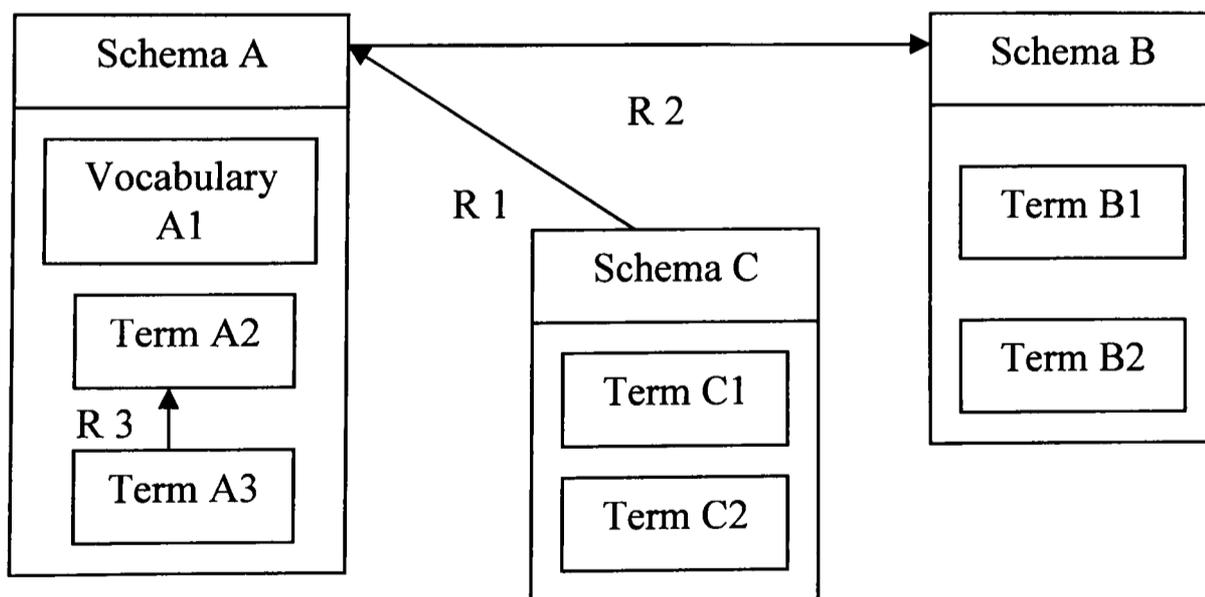


Figure 5.7 The Relationships among Schemas or between Schemas and Terms or Vocabularies

In the diagram 5.7, the relationships 1 and 2 (R1 and R2) refer to that schema C is played in front of schema A, and the schema B will be done finally. Furthermore, the R3 relationship indicates that term A2 must be performed after operating term A3.

#### **5.4.2. Define Data Elements for Schemas**

The table 4.1 (appendix C) shows a set of data elements to construct a schema, which are used to describe the structure and semantic information of a process. This table consists of four main categories: general, contribute, annotation, and relation. The general category contains some data elements that are used to describe the basic information of a schema, such as the name, identifier, and description of this schema. The contribute category shows the data elements to represent the information about the contribution of a schema, such as the name of the author. The category of annotation offers some data elements to describe the information of the comments to a schema, such as the state of this comment. The relation category presents some data elements used to describe the relationship information about a schema, such as the version numbers of terms in a schema.

#### **5.4.3 Define Data Elements for Vocabularies**

The table 4.2 (appendix C) shows a set of data elements to construct a vocabulary, which are used to describe the structure and semantic information of a collection of units. This table consists of five main categories: general, contribute, annotation, technical, and relation. The representation of the classes of general, contribute, annotation, and relation are similar to the discussion in section 5.4.2.. Furthermore, the technical category provides some data elements to describe the technical information about a vocabulary, such as on which operating systems this vocabulary can be used and the tutorial about how to use this vocabulary.

#### **5.4.4. Define Data Elements for Terms**

The table 4.3 (appendix C) shows a set of data elements to build a term, which are used to represent the semantic information of a unit such as a learning unit. This table is divided into five big categories: general, contribute, annotation, technical, and relation. The description of these classes and subclasses are similar as what we did in the section 5.4.3.. The difference is that in the category of relation, it only needs to define the relationships among terms, not between vocabularies and terms.

### **5.5. An Application of Schema-Driven Approach in E-Learning**

The following diagram shows a concrete description about how to support learners and teachers to implement the individualized creation and control of instructional procedures by using the approach, which could be the key content in building and performing personalized pedagogy styles.

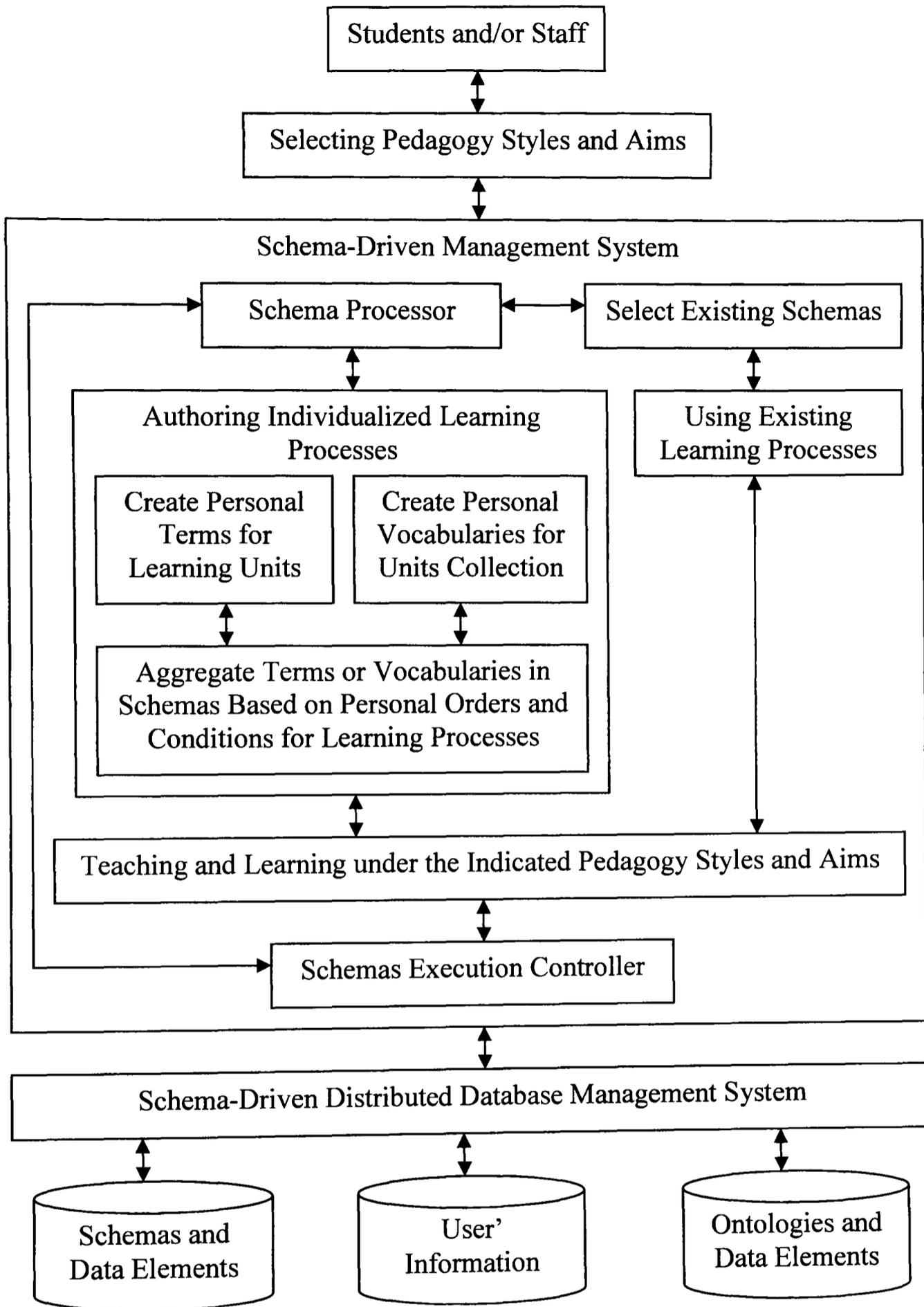


Figure 5.8 The Application of Schema-Driven Approach in the E-Learning Area

*Schemas Execution Controller* is a collection of application programs that is used to implement the individualized control of teaching and learning processes during their running. Through changing the values of data elements in schemas, the directions of procedures could be coordinated in terms of the new demands of learners and/or teachers.

The application of a schema-driven approach is presented in the above diagram. As the details of the functions of this approach have shown in the above sections, so here we provide a summary of this application.

- Under the indicated instructional styles and aims, teachers and/or learners could design their personal educational procedures. For example, a student and the relevant staff could select the guided discovery manner and decide their particular aims. Next this approach could support them to get the preferred learning units, set their special sequences of these units, make an individual schedule, and lock the indicated units (e.g. exams and the following one). Then they could start their travel in a certain domain of knowledge.
- During teaching and learning, this approach could support learners and/or teachers to implement the individualized control of their procedures. For instance, under the guided discovery style, any learning unit could be locked by learners and teachers when they design their special procedures. Then during their instruction, according to the results of exams or assignments, or other changes of users' circumstances, learners could go to any unit indicated by users. This could be supported by the module of "schema execution controller" in the approach.

In this chapter, we built a schema-driven approach and provided an example to demonstrate the application of this method in e-learning. Next, a flexible virtual learning environment based on this approach will be designed.

## ***Chapter 6 Design a Flexible Virtual Learning Environment***

In this chapter, we design a flexible virtual learning environment (VLE) over the schema-driven approach and computing technologies. It consists of three sections. The first section describes the technical framework and two-state model of this e-learning system. The second section shows the allocation of the components of this system to users. In the third section, a set of flowcharts are completed in order to design the key functions of this system based on the modules presented in Chapter 5 (section 5.5.).

## **6.1. Description of a Flexible VLE**

### **6.1.1. Roles in a Flexible VLE**

In this thesis, a flexible virtual learning environment based on the schema-driven approach comprises five kinds of players:

*Student* is to anyone who wants to learn or just have an acquaintance with some specified knowledge domain.

*Teacher* is any one who teaches students the knowledge domain indicated by students, staff, or students and staff.

*Author* is a student, a staff, or a student and relevant staff who have rights to create individual and/or common terms, vocabularies, and schemas in a flexible virtual learning environment.

*Evaluator* is a student, a staff, or a student and relevant staff who are in charge of assessing work.

*Administrator* is anyone who is responsible for the management of a flexible e-learning system. There are some classifications in this role, such as system and finance administrators.

### **6.1.2. A Framework of Flexible VLE**

The following diagram shows a working environment of this flexible e-learning system controlled by the schema-driven approach. Some building blocks of this system have been discussed before, such as the schema-driven management system and relevant things (Chapter 5). Other components are described as follows:

*The Client/Server Infrastructure* is a platform on which applications and services are performed in terms of client/server mechanism. The system in this research is built on it.

*The Web Services and Applications layer* is a collection of services and applications deployed on the Web. For example, Enterprise Resource Planning (ERP) can support various business processes to provide the services required by customers [332].

*The Data Layer* contains a set of databases such as the databases to store schemas, ontologies, and metadata in the e-learning area, as well as learning materials themselves.

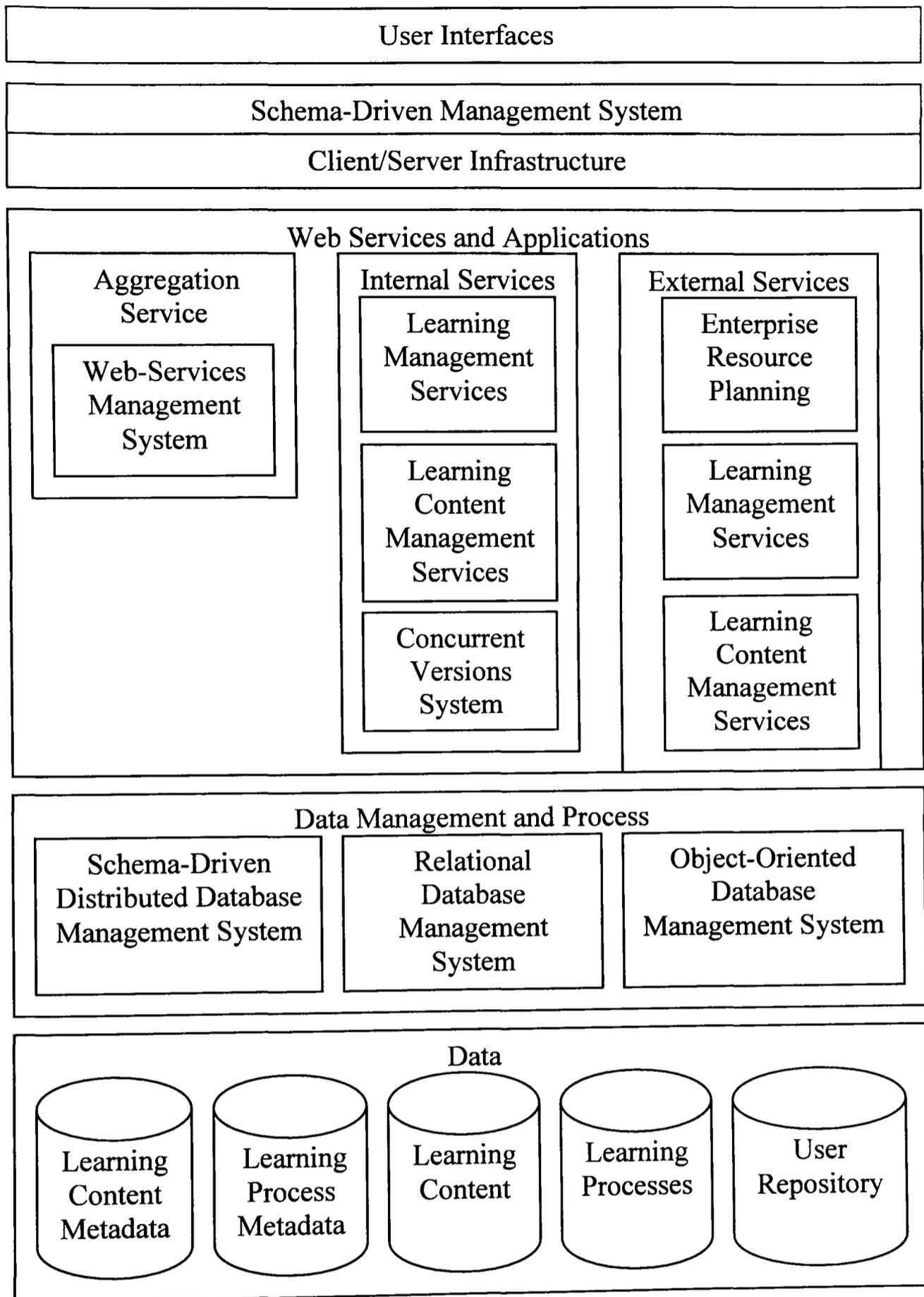


Figure 6.1 The Framework of Flexible Virtual Learning Environment

### 6.1.3. A Model of Flexible VLE

We build a model to represent the two states of a flexible virtual learning environment, which is Web-based, schema-driven, and established on the client/server infrastructure. This model is designed based on widely-used standards such as UK LOM Core and IMS Learning Design (section 3.4. of Chapter 3). The main feature of this model is that it describes the procedure of the transformation of a flexible virtual learning environment from initial state to running environment. The

initial state presents the basic configuration of this system. Also the running environment shows the class and package model of the system. In detail, according to users' requirements, the system components will be allocated to users on the Web. Then this system enters into the running environment in which users do their teaching and learning.

The model is presented with the diagrams 6.2 and 6.3, and the major components in this model are described as follows:

*The Learning Process Management System* is a collection of applications to support the flexible management of learning units and processes. According to users' demands, this system could build and control personalized learning processes through assembling the semantic information of learning units. The detailed information in this area is represented with the flowcharts (section 6.3.).

*The Semantic Information Management System* is a repository of applications to be responsible for the management of databases of schemas, ontologies, and data elements. This system is designed based on the schema-driven distributed database management system.

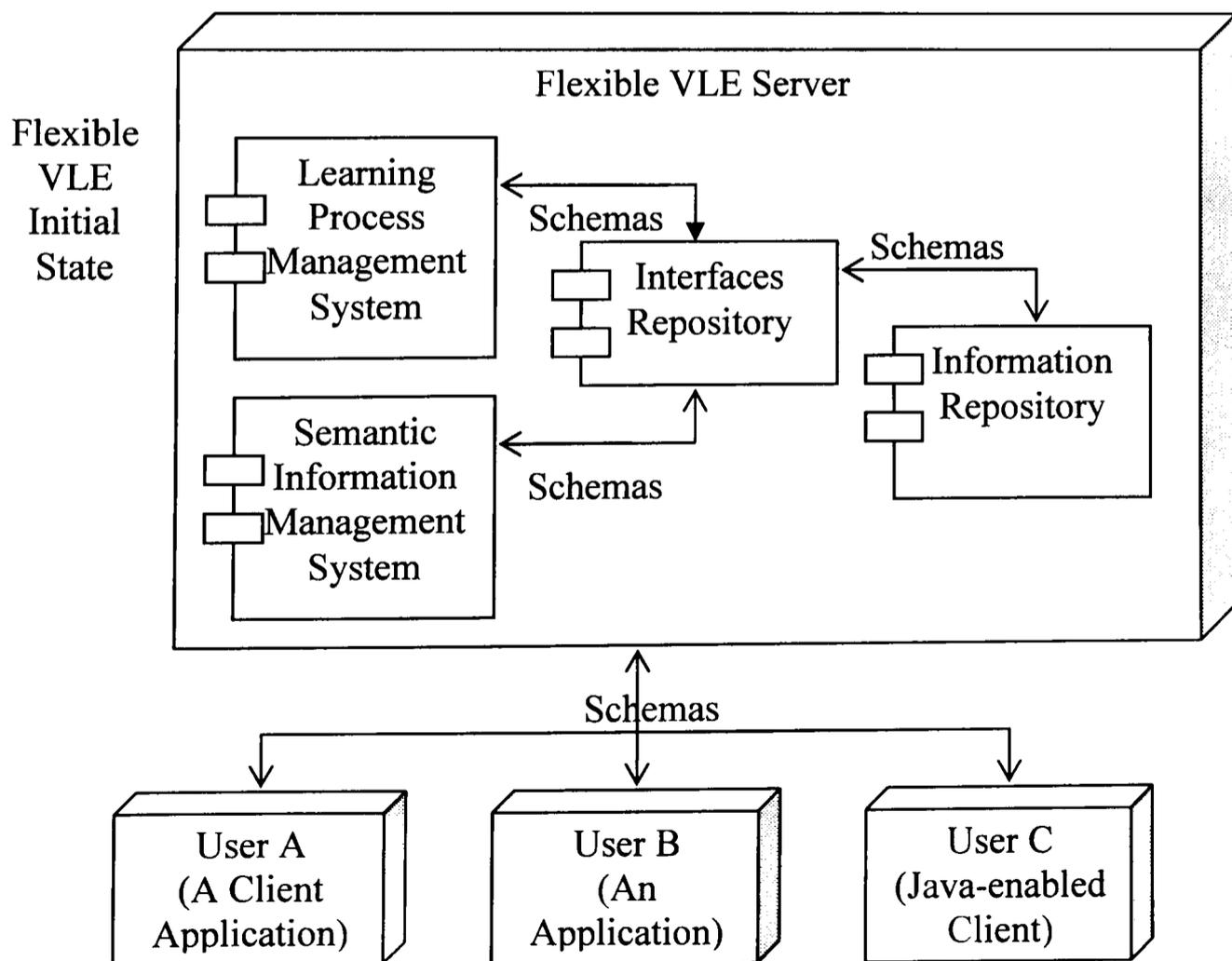


Figure 6.2 The Initial State of Flexible Virtual Learning Environment

*The Interfaces Repository* contains a set of interfaces such as user interfaces and APIs, which could support the interaction between users and this model, and among the components of the model. The detailed description is shown in the section 6.3..

*The Information Repository* is a collection of the databases of schemas, ontologies, and metadata. Every database is mainly composed of four types of tables: schema table, vocabulary table, term table, and relationship table. These items are listed in the appendix C.

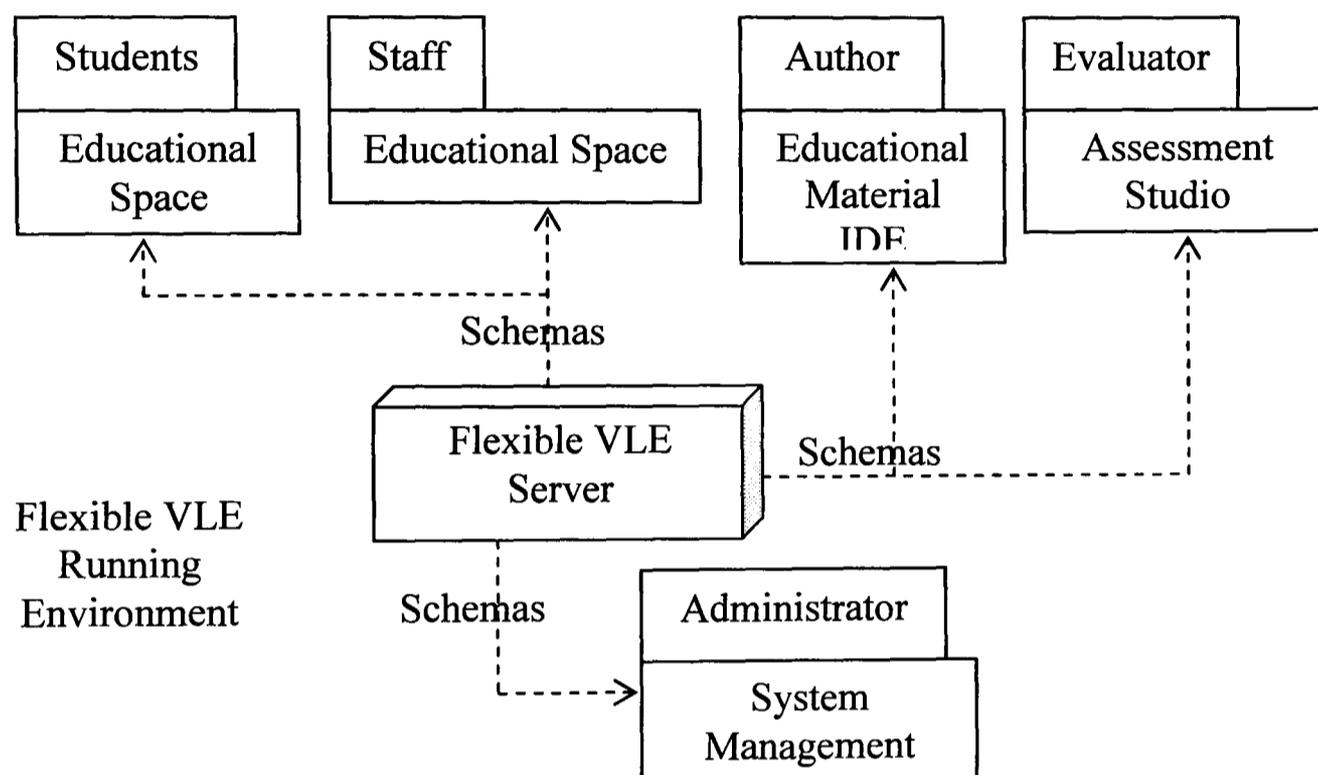


Figure 6.3 The Running State of Flexible Virtual Learning Environment

*The Educational space* is an interesting and powerful teaching and learning environment, which could provide the functions for users to flexibly control their instructional processes and units by using a learning process management system.

*The Educational Material IDE* refers to the software that could support authors to create personalized schemas and terms based on a learning process management system and a semantic information management system.

*Assessment Studio* is a system for evaluators to assess the learning results of learners by using a learning process management system. Next based on the assessment, teachers who could also be evaluators may control the procedures of learners.

*System Management* refers to a set of applications that could be used to maintain, update, and manage a flexible virtual learning environment by system administrators.

## 6.2. The Allocation of System Components to Users

The following diagram illustrates the allocation of the building blocks in a flexible VLE to users. The components in this picture can be discussed as follows:

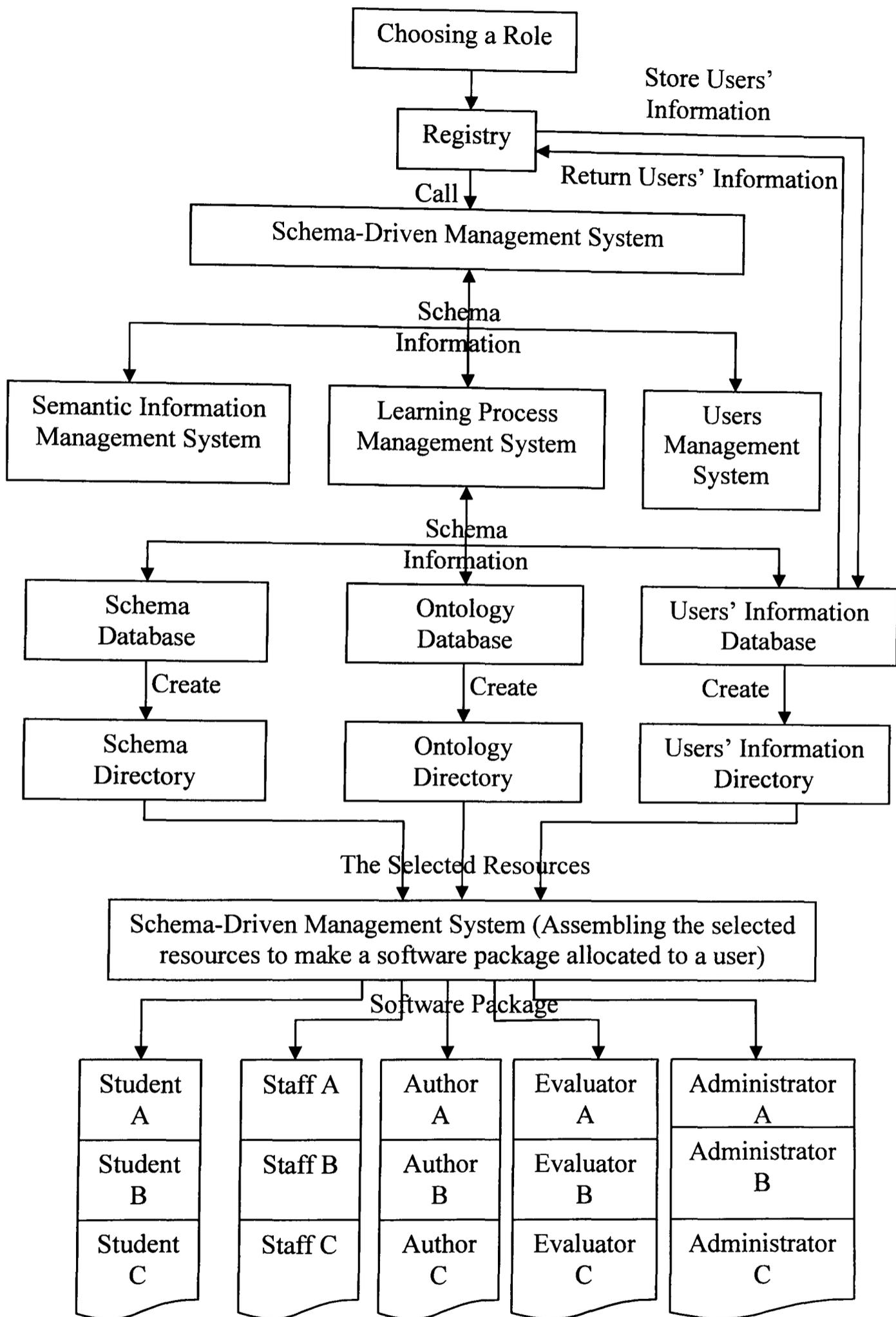


Figure 6.4 The Allocation of the Building Blocks in a Flexible VLE

Notes: *Schema Information* is a package made up of standardized schemas, vocabularies, terms, and data elements.

*Choosing a Role* allows a user to select a role from student, staff, evaluator, author, and administrator. A dialog box is presented to users by a learning process management system, which could support users to set up their preferred roles.

*Registry* is an application through which users may input the required information in terms of their roles. Next the information would be transferred to a users' information database on the server side, and an email attached all of useful information such as user name and password would be sent to users.

*Schema Database* contains all of schemas and relevant data elements which are the personalized descriptions of semantic information of learning processes. The databases of schemas are built on the server side. A schema directory is an individual copy of this database on a client.

This diagram shows how the components of a flexible e-learning system could be delivered to various users, such as the allocation of learning process management system, semantic information management system, and databases. The detailed analysis of this function has been completed in one of my publications [326].

### **6.3. Design a Learning Process Management System**

A learning process management system is a key component of flexible virtual learning environment. Here the flowcharts 6.1-6.4 (appendix A) have been constructed to present the individualized management of e-learning Web services and applications according to the needs of users. These flowcharts have been divided into four parts in terms of the modules displayed in the figure 5.8 (Chapter 5): the creation of individual terms, vocabularies, and schemas, and the individualized control of processes. Next, we will show the design of these parts under a range of styles and various aims.

#### **6.3.1. Terms for Personalized Learning Units**

As shown in the picture 6.1, learners and teachers need to register as the role of author and enter the module "Using Existing Learning Processes". Next they may select existing procedures to start their instruction or create their individual ones. The following three pictures could support users to choose their interested learning units such as courses, modules, and lectures. Then users could design their particular terms to describe their preferred semantic information of units. In detail, in the module of "Create a Personalized Term for Lecture 1", learners and teachers could set an order

between the units 1 and 3, which could be captured by machines. Also users may decide to lock these learning content based on their needs. In the picture of “Create a Personalized Term for Lecture 2”, the unit 3 could be in front of the content 2, and users could lock both of them. By using the similar functions, the test A could be behind the unit 2. The order of learning materials following the exam A could be designed as units 9, 5, 6, and 8, exam B, units 10, 16, and 11, and test C. All of these resources could be locked according to users’ demands, and are presented in the below diagram.

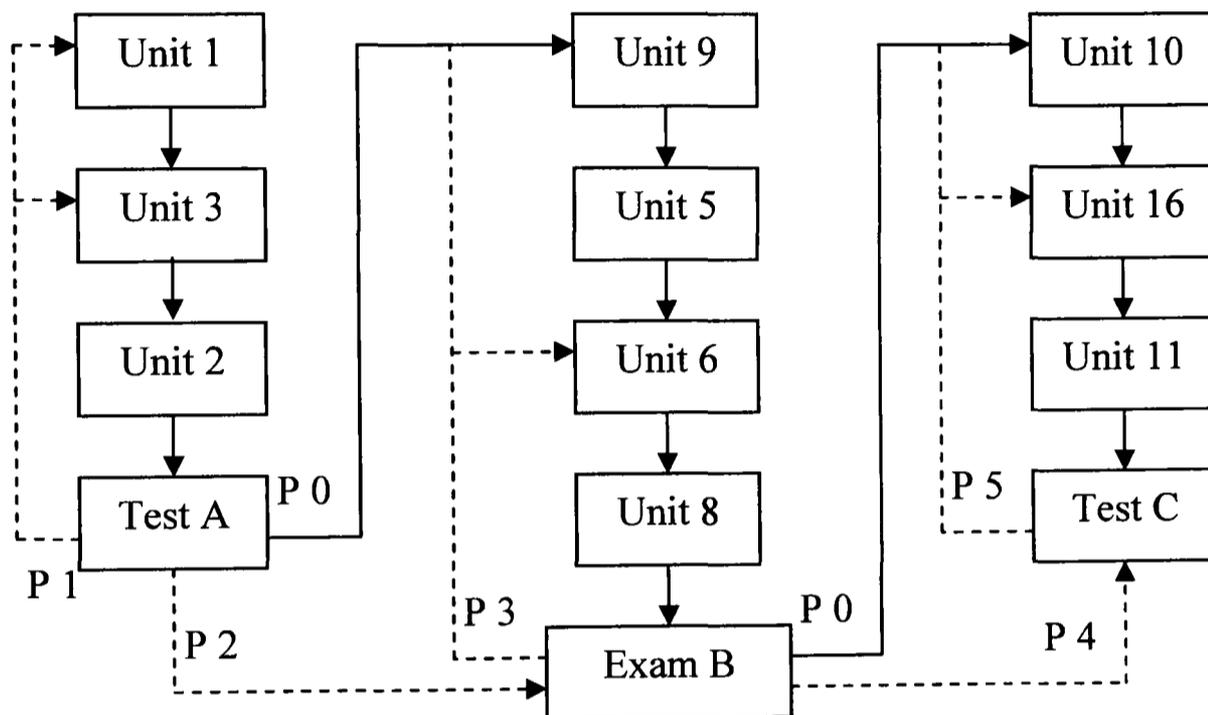


Figure 6.5 Design an Individualized Learning Process

This picture presents an educational procedure with complex relationships among the units. The details can be described as follows:

- The “P 0” refers to the main road of this process. It defines the linear order of these learning content, which asks learners to complete the former unit before they do the later one.
- The “P 1” points that some learners who did not pass the test A should return to the previous units. As teachers locked the “Unit 9”, so these learners could not open this content to continue the procedure “P 0”. In addition, learners could discuss with teachers to decide which unit or units should be repeated.
- The “P 2” means that a few students who obtained very good results in the “Test A” could talk with teachers to unlock the “Exam B” for these learners to attend directly.
- The “P 3” refers to that If the learners could not complete the “Exam B”, they could study the material “Unit 9” or other content such as “Unit 6” which should

be selected based on the weaknesses of learners. If these learners could accomplish this exam with good marks, teachers would open the content “Unit 10” for these students. That is, the learners was in the procedure of “P 0”.

- The meaning of “P 4” is that the learners who entered the “Exam B” and got the outstanding results could contact their teachers to directly do the “Test C”.
- The “P 5” shows that the learners who did not finish the “Test C” should go back to perform units 10, 16, and 11. The students could choose one or more of these learning resources in terms of the analyses of their exam results.

Except for the personalized designing of instructional procedures by users, a learning process management system could automatically give the titles, identifiers, version numbers, and addresses of the units indicated by users. Finally, after completing the authoring of terms representing various individualized learning resources, users could go to create the vocabularies or schemas for their personal content collections or procedures.

### **6.3.2. Vocabularies for the Collections of Learning Units**

The creation of vocabularies used to describe the personalized semantic messages has been specified in the flowchart 6.2. This work may be achieved in the similar way as the authoring of terms. The main difference is that except for the designing of the relationships among vocabularies, here it is also required to import the titles and version numbers of terms selected by users into their pointed vocabularies.

### **6.3.3. Schemas for Personalized Learning Processes**

The flowchart 6.3 presents the building of individual instructional procedures of learners and teachers. The main difference from creating terms and vocabularies is that users need to input some information to tell computers which terms or vocabularies are in their established schemas. Here users could author more particular educational procedures including their personal items, and all of these processes could be shown on screen.

### **6.3.4. Management of Processes**

In the picture 6.4, we design a set of steps to control the performances of users during running the chosen learning procedures. At first, a learning process management system could make the orders of the vocabularies or terms in a schema by using the values of data elements “relationship” and “version number”. Also the similar method could be adopted to define the order of terms in a vocabulary. Next

the proper procedures could be presented to learners, including their designing orders, conditions, and content. Then under their selected teaching and learning manners, users could start their instruction. Finally, during the running of these procedures, by managing the open rights of the units, users could flexibly coordinate the directions of processes to meet their practical requirements.

So far, we have completed a technical specification of flexible virtual learning environment based on the schema-driven approach. Next, a tool will be implemented to demonstrate the flexible creation and control of e-learning Web services and applications.

## ***Chapter 7 Implement a Flexible Virtual Learning Environment***

This chapter shows the screen snapshots of a flexible virtual learning environment that is implemented by using JBuilder 9 development tool. It consists of four sections. The first section gives the reasons for the selection of this integrated development environment. The second section represents the creation of various teaching and learning processes. The third section presents the flexible management of instructional procedures during their execution. The final section describes the management mechanism of version numbers and concurrency control of learning units and processes.

### 7.1. Selection of Development Tool

In the thesis, JBuilder9 [333] was selected to complete a prototype in the research subject. This tool is an integrated development environment (IDE) for java programming. It was a free tool (when I downloaded it) and supported the implementation of the functions required in this research. In detail, the tool provides a set of easy-used functions in the Web services development, such as drawing the pre-designed button, toggle, checkbox, label, textfield, textarea, scrollbar, tree, and/or table to the things that users are programming. Also it supports the creation of SQL databases and XML files. All of them made sure the building of the prototype in this thesis. In the area of Java development, there are some other free IDEs such as NetBeans [334] and Eclipse [334]. These software may have their special advantages to provide different functions. The research does not aim to compare these tools. The main work in this chapter is to build a prototype to implement flexible e-learning, and JBuilder9 achieved this goal.

### 7.2. Describe and Assemble the Semantics in E-Learning

At first, varieties of schemas and ontologies were imported into the main frame of the flexible virtual learning environment, and were presented as all kinds of existing learning processes and units to users (screen snapshots 7.1 and 7.2). In detail, figure 7.1 showed there were no learning units and processes presented in the frame. Next, during the initialization of the software, any unit and process distributed on the Web were collected by the system if the data had been available. Also the relevant semantic information of the resources was obtained by the tool, such as the titles and addresses of units. Then, figure 7.2 displayed the found existing learning content in the main frame of the flexible VLE.

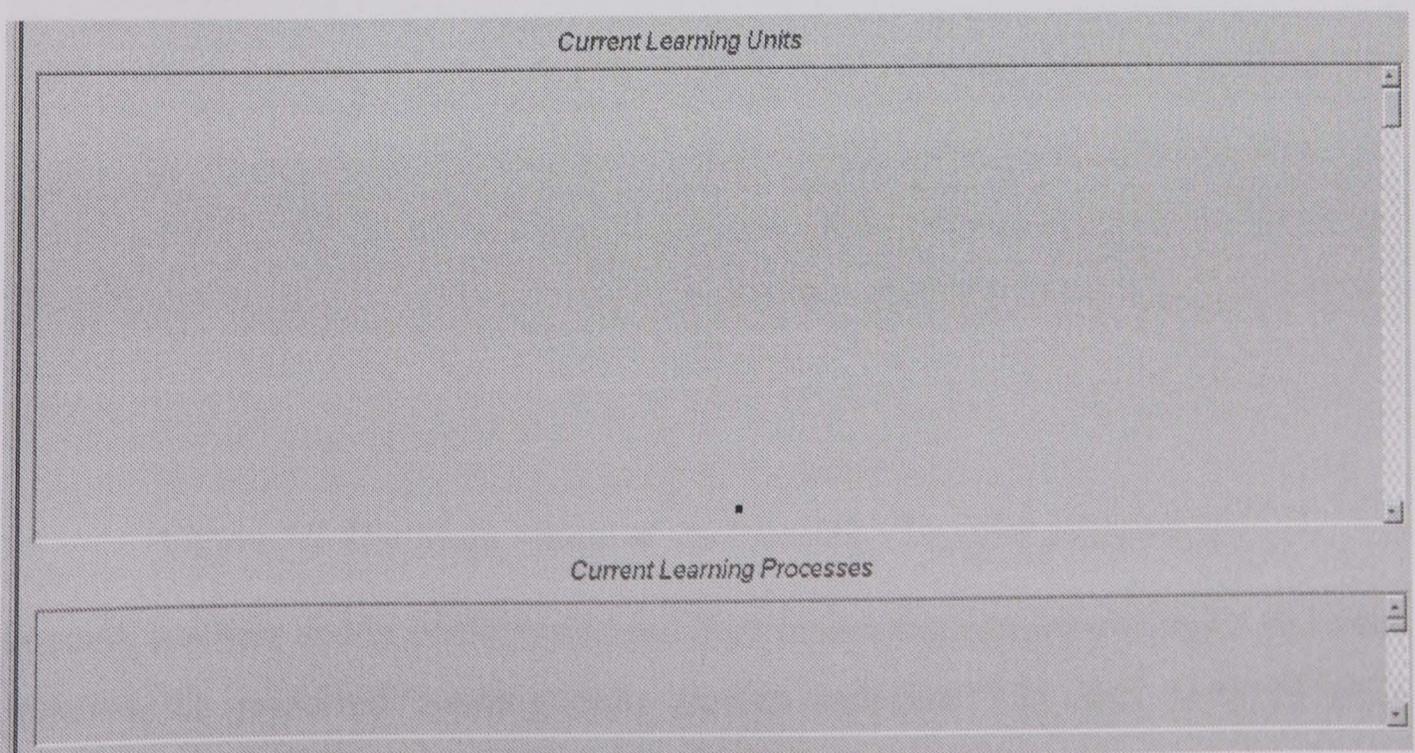


Figure 7.1 The Main Frame of the Flexible VLE before Initialization

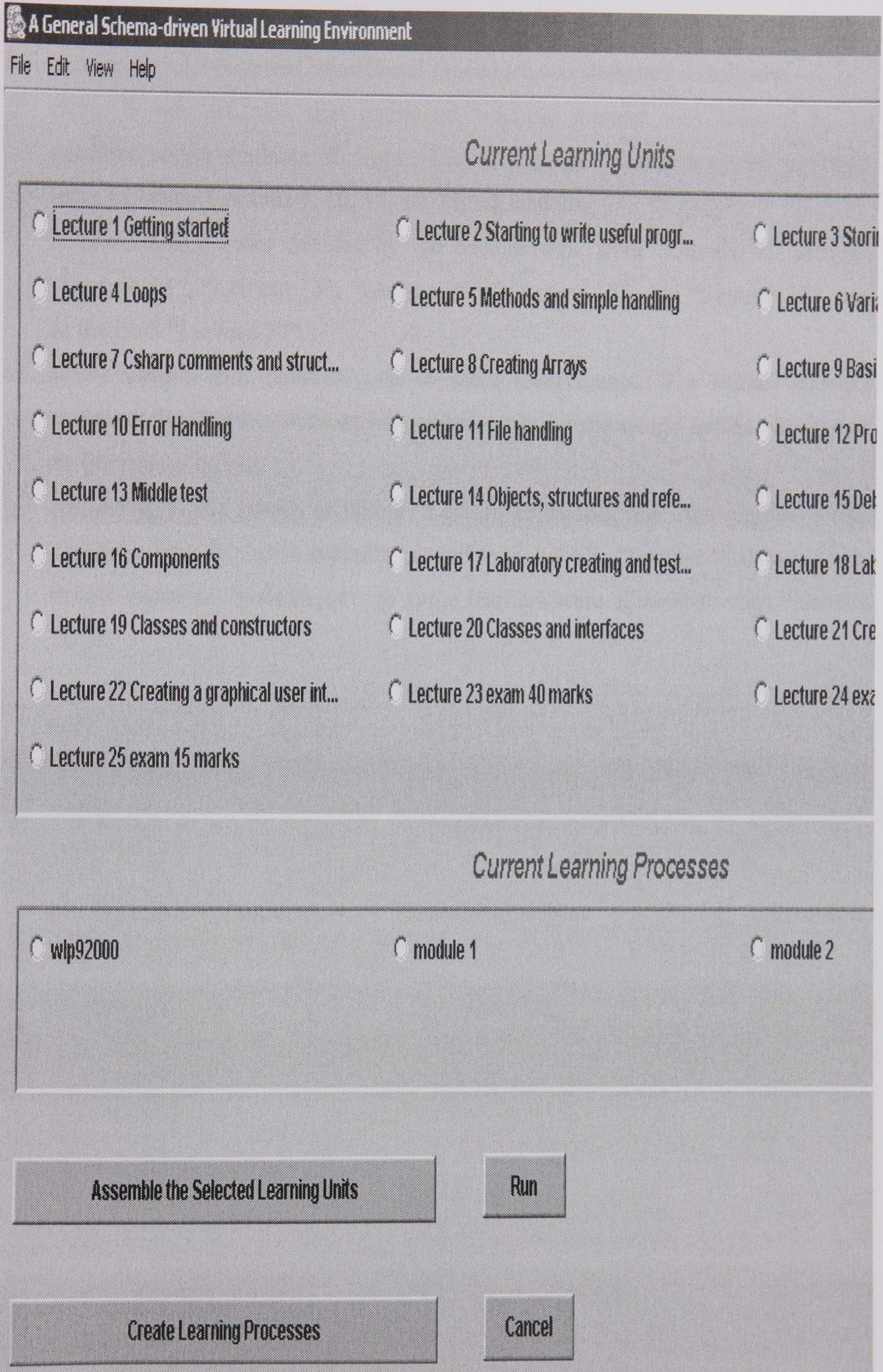


Figure 7.2 The Main Frame of the Flexible VLE after Initialization

Second, teachers and/or students decided their interesting educational styles and aims, selected the preferred learning units (screen snapshot 7.3), and designed their individualized orders between the units and particular conditions that learners should

meet in order to execute these instructional items. As an example, the detailed information about a concrete educational procedure was designed as follows:

- Here, it was assumed that command teaching manner was selected by an educator and/or students. In figure 7.3, the teacher selected a set of particular learning units: Lectures 7, 10, 13, 14, 17, 23, and 24.
- A personalized order decided by the teacher was: from “Lecture 7”, through “Lecture 14”, “Lecture 13”, “Lecture 10”, “Lecture 17”, and “Lecture 23”, and to the final “Lecture 24”.
- Every chosen unit included one or more assignments. If a learner did not complete the learning content in a certain unit, he/she would not be allowed to do the following one.
- According to the results of taking “Lecture 13 middle test”, the teacher would determine whether some students needed to go back to “Lecture 7”, some others should return to “Lecture 14”, or some learners were allowed to start “Lecture 10”.
- Learners would be asked to complete “Lecture 23” before they can do “Lecture 24”.

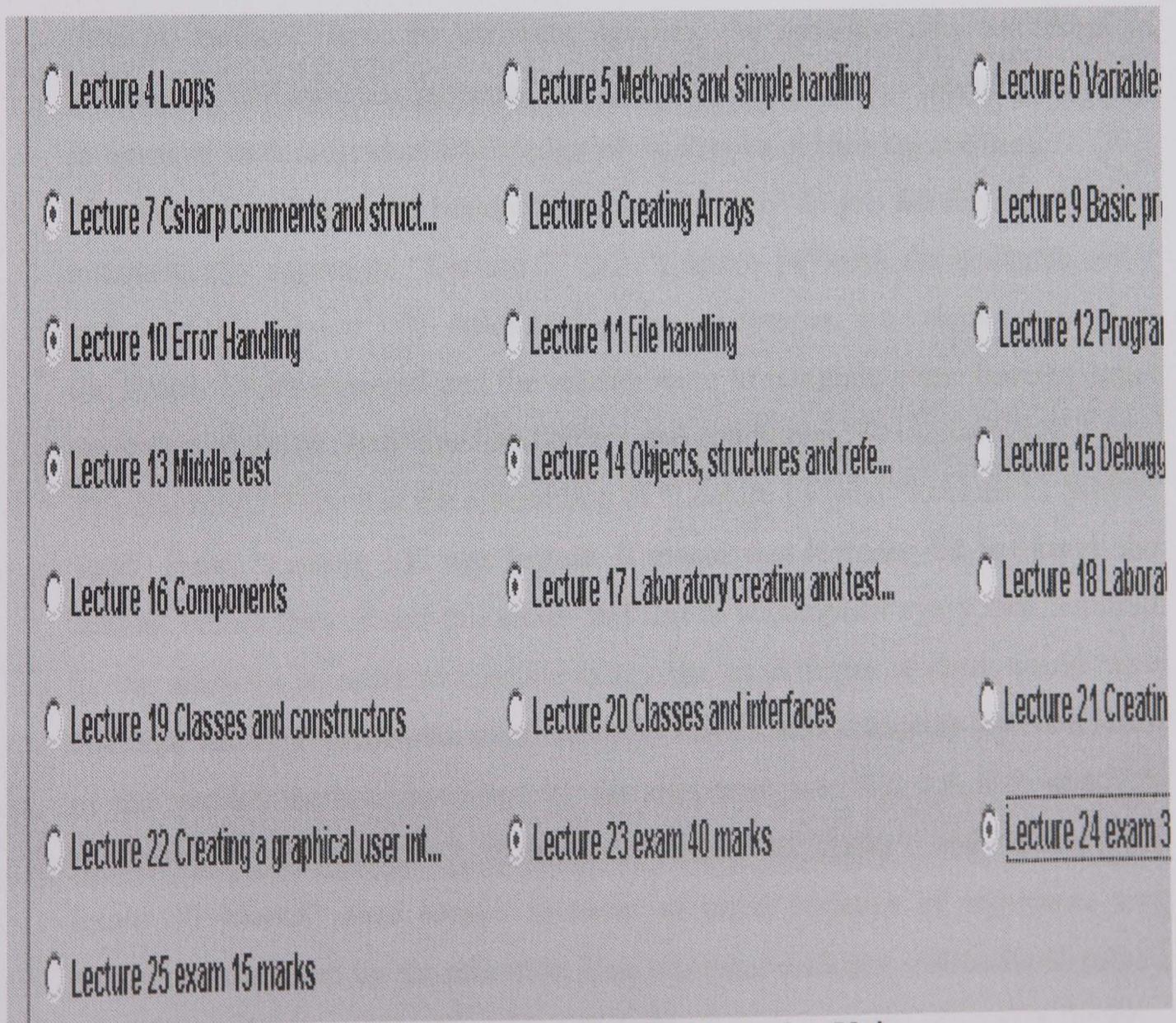


Figure 7.3 Select the Individual Learning Units

Next, an educational process would be developed in terms of the above messages. The instructor clicked the button “Assemble the Selected Learning units” in Figure 7.2. Then, Figure 7.4 was opened, in which the educator aggregated the chosen learning units according to the personalized order and conditions discussed above. The detailed information was represented in the following:

- Figure 7.4 showed the environment for users to integrate the selected learning units. Here, the teacher clicked the button “Select” to open the dialog boxes (figures 7.5 and 7.6) to get “Lecture 7” from a list of the selected learning units.
- The teacher clicked the button “Receive”. Then, “Lecture 7” appeared in the area of “Source Learning Unit” as well as its version number and address (figure 7.7). The same way was used to make “Lecture 14” to appear in the area of “Target Learning Unit” (figure 7.8).
- Based on the pre-designed order by the teacher, “Lecture 7” was put in front of “Lecture 14” through selecting the item “In front of” (figure 7.8). Also “Lecture 7” was locked by selecting the item “Yes” (figure 7.8).
- “Lecture 14” was locked by selecting the item “Yes” (figure 7.8), which ensured that any student should finish the indicated assignments in “Lecture 7” before they go further. Here, for different learners, the educator may ask them to accomplish different assignments, which is very valuable for teaching students in terms of their individual knowledge background and learning abilities.
- The instructor clicked the button “Save and Refresh” to ask the flexible VLE to automatically aggregate “Lecture 7” and “Lecture 14” with the designed order and condition (figure 7.8). After saving these messages, the values occurred in the figure 7.8 disappeared and the teacher went to integrate other learning units according to his/her individualized orders and conditions.
- The diagram 7.9 showed the assembling of “Lecture 14” and “Lecture 13 Middle Test”. Here, “Lecture 13” was locked. It means that learners did not know the content before they attend this exam and had to accomplish every task required by the educator in order to take the test. Also, as different students could have different learning results, the instructor may ask them to complete different tasks.
- In the similar method described by the diagrams 7.4, 7.5, 7.6, 7.7, and 7.8, “Lecture 10”, “Lecture 17”, “Lecture 23 Exam 40 Marks”, and “Lecture 24 Exam 30 Marks” were locked in order to build varieties of sequences and conditions designed by the educator. This provided different instructional paths for different learners, which made users to build their personal processes freely.

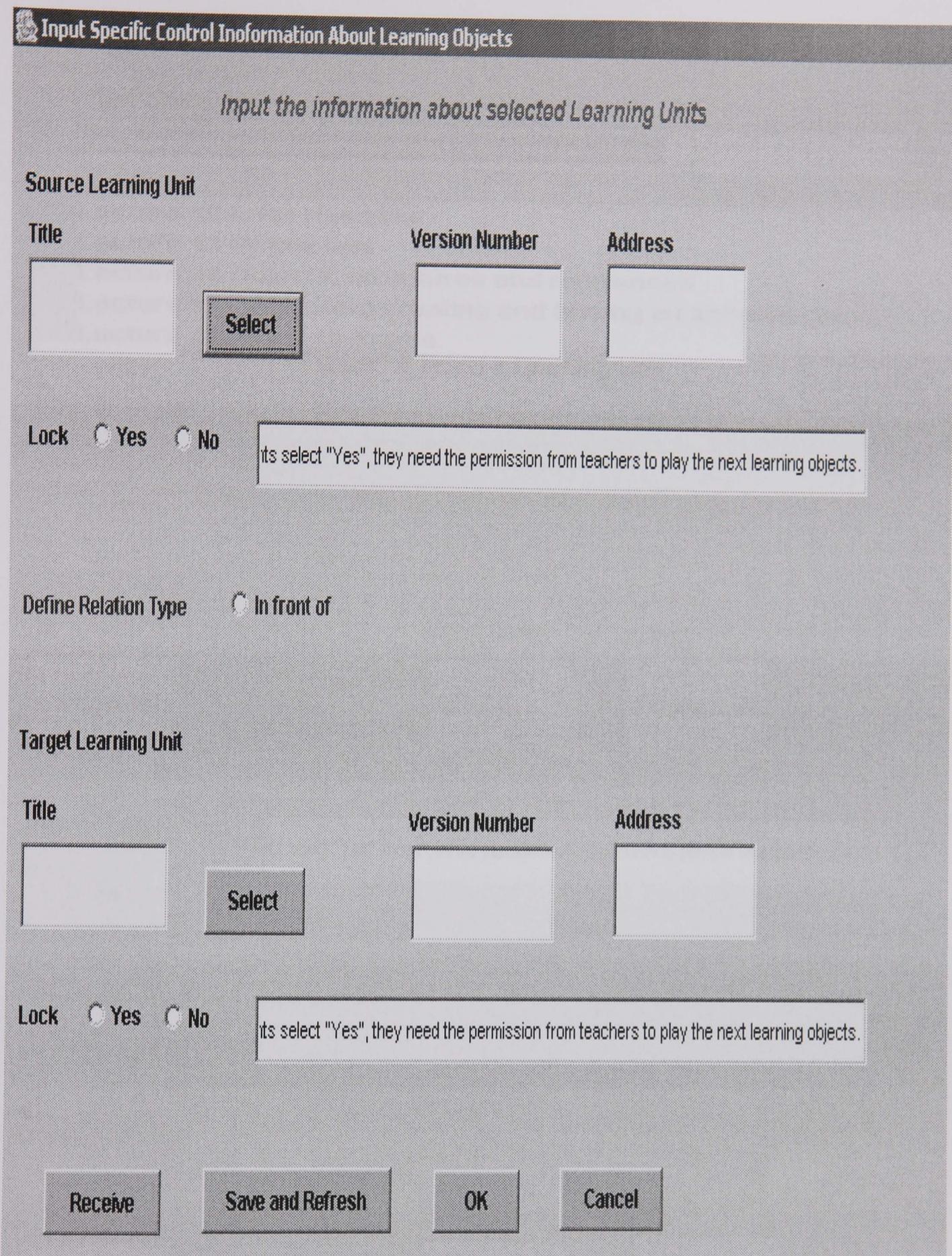


Figure 7.4 The Environment for Users to Aggregate the Selected Learning Units

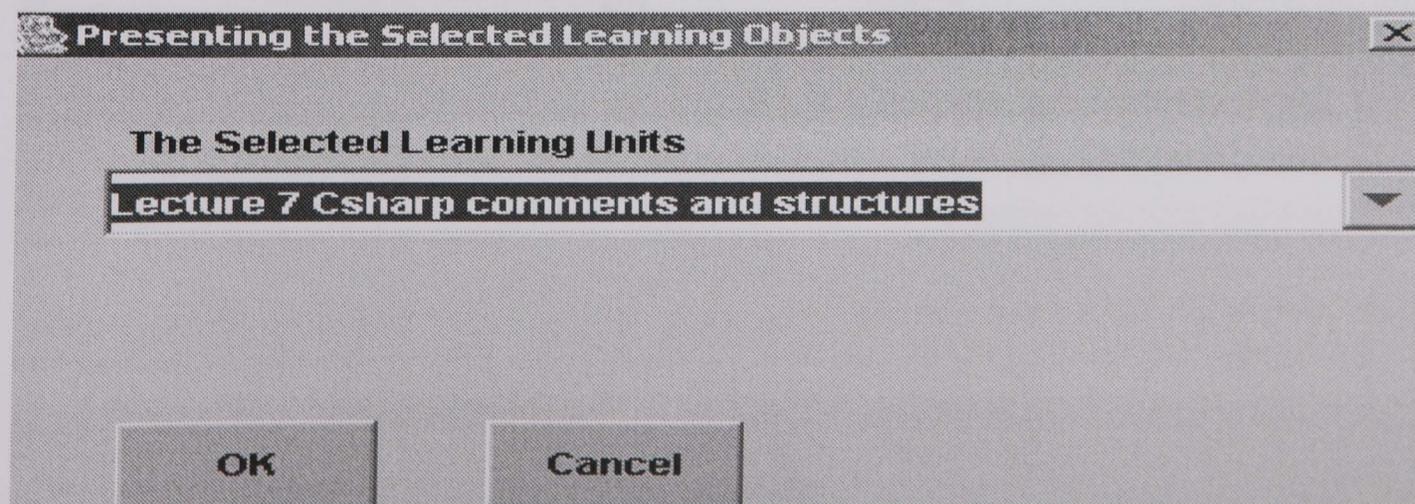


Figure 7.5 A List of the Selected Learning Units

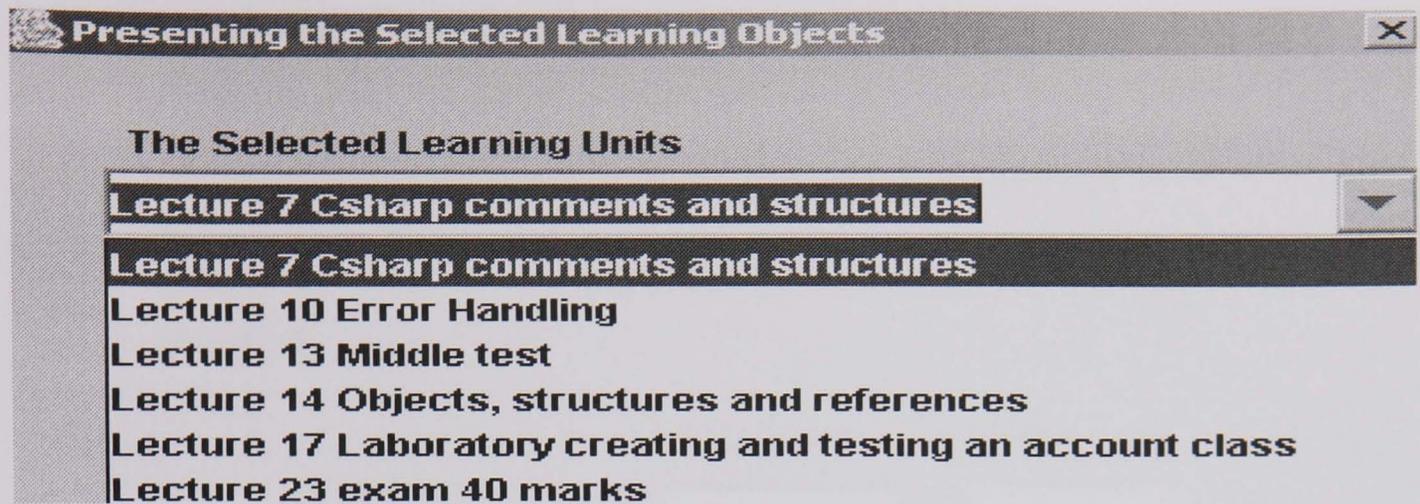


Figure 7.6 Select a Learning Unit

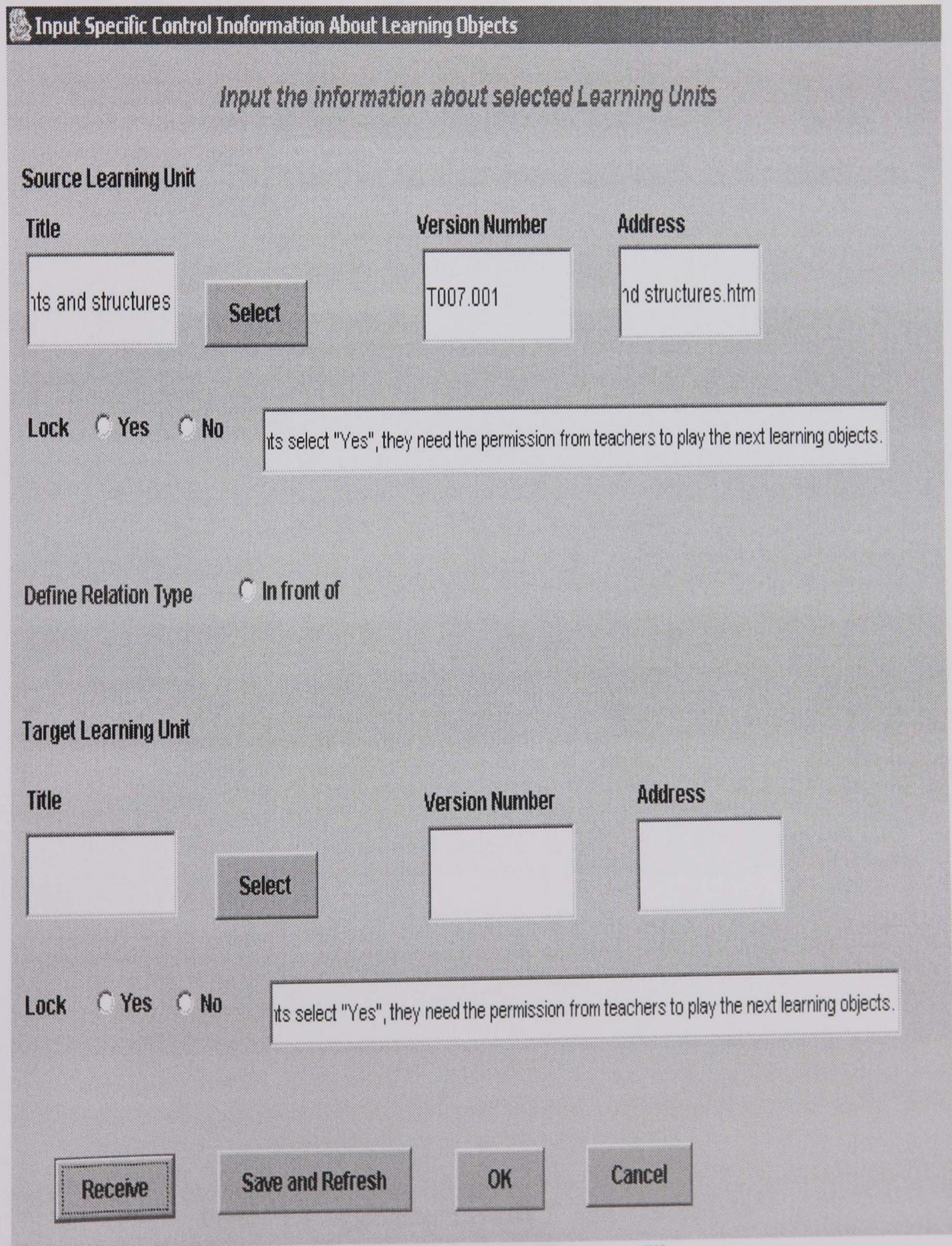


Figure 7.7 Import the "Lecture 7"

Input the information about selected Learning Units

Source Learning Unit

Title

nts and structures

Select

Version Number

T007.001

Address

nd structures.htm

Lock  Yes  No

its select "Yes", they need the permission from teachers to play the next learning objects.

Define Relation Type  In front of

Target Learning Unit

Title

es and references

Select

Version Number

T014.002

Address

nd references.htm

Lock  Yes  No

its select "Yes", they need the permission from teachers to play the next learning objects.

Receive

Save and Refresh

OK

Cancel

Figure 7.8 Aggregate "Lecture 7" and "Lecture 14"

Input the information about selected Learning Units

Source Learning Unit

Title

es and references

Select

Version Number

T014.003

Address

d references.htm

Lock  Yes  No

its select "Yes", they need the permission from teachers to play the next learning objects.

Define Relation Type  In front of

Target Learning Unit

Title

ure 13 Middle test

Select

Version Number

T013.001

Address

3 Middle test.htm

Lock  Yes  No

its select "Yes", they need the permission from teachers to play the next learning objects.

Receive

Save and Refresh

OK

Cancel

Figure 7.9 Aggregate "Lecture 14" and "Lecture 13"

Then, the educator clicked the button "OK" in the diagram 7.9 and went to the main frame of the flexible VLE (figure 7.2). By pressing the button "Create Learning

Processes”, a dialog box (figure 7.10) was shown to the teacher, in which the selected learning units were integrated into an educational process (figures 7.11 and 7.12).

- In the figure 7.11, a name of this process was given by the instructor: “Learning Process 1”. By clicking “Auto Set”, the version number of this process was automatically provided by the system, such as “S005.001”.
- The teacher clicked the button “Select” in the area of “Target Learning Unit” (figure 7.11), and the list of the selected units was presented to him/her (figure 7.6). Next, the staff imported “Lecture 7” into the dialog box by using the button of “Receive Selected Learning Unit” (figure 7.11).
- Through clicking the “Save and Refresh” button, the semantic information of this unit was added into the learning process (figure 7.11). The similar operations have been done to integrate other learning units required by the educator (figure 7.12). The semantics contains the names, addresses, and version numbers of units, especially the personalized orders and conditions.

**Build Personal Learning Activities**

*Create Individual Learning Processes*

**Source Learning Process**

Title  **Auto Set** **Select** Version Number  Address

Lock  Yes  No

Define Relation Type  Contain

**Target Learning Unit**

Title  **Select** Version Number  Address

**Receive Selected Learning Unit** **Save and Refresh** **OK**

Figure 7.10 The Environment of Creating Learning Processes

**Build Personal Learning Activities**

*Create Individual Learning Processes*

**Source Learning Process**

**Title**  **Version Number**  **Address**

**Lock**  Yes  No

**Define Relation Type**  Contain

**Target Learning Unit**

**Title**  **Version Number**  **Address**

Figure 7.11 “Learning Process 1” and “Lecture 7”

**Build Personal Learning Activities**

*Create Individual Learning Processes*

**Source Learning Process**

**Title**  **Version Number**  **Address**

**Lock**  Yes  No

**Define Relation Type**  Contain

**Target Learning Unit**

**Title**  **Version Number**  **Address**

Figure 7.12 “Learning Process 1” and “Lecture 14”

Finally, the instructor clicked the button “OK”. The learning procedure created on the personalized orders and conditions was presented to users in the main frame of the flexible VLE (figure 7.13).

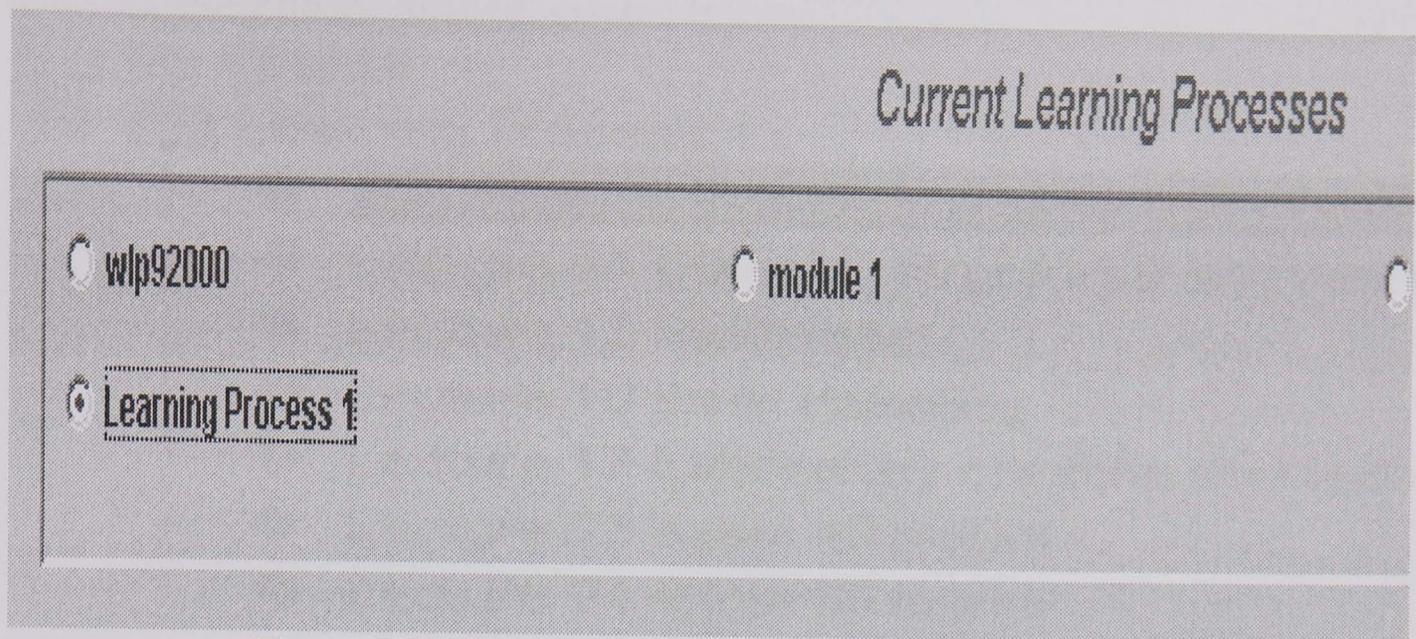


Figure 7.13 The Created Personalized Learning Process

### 7.3. Individualized Control of Education Processes

During the execution of the process, the instructor did the individualized control to “Learning Process 1” according to his/her new requirements. The details were represented as follows:

- Learners selected “Learning Process 1” (figure 7.13) and clicked the button “Run”. The relevant learning environment was shown to students, in which the content of this process was described (figure 7.14).
- When learners tried to open “Lecture 7”, a dialog box was shown to them to ask for the permissions from the teacher (figures 7.15 and 7.16). However, there could be two possible answers. On the one hand, in the diagrams 7.17 and 7.18, some learners did not pass the assessments of the educator, so they had to return to the indicated units to do further learning. On the other hand, in the figures 7.17, 7.19, and 7.20, some learners got the permissions to open “Lecture 7”.
- In the following procedures of learning of students, the staff unlocked “Lecture 10” for some learners in the similar way to open “Lecture 7” (figures 7.17, 7.19, and 7.20), as these students got the good marks in doing “Lecture 13”.
- Some learners returned to “Lecture 7” as their worse results in “Lecture 13” (figures 7.17 and 7.18).
- For a few students who obtained excellent results, thus the teacher opened “Lecture 23” for them (figures 7.17, 7.19, and 7.20). It means that these learners jumped the pre-designed units and directly entered the final exam. If they passed this exam, they would save a lot of time and money as they did not need to

execute their omitting units. If they were not successful, they would go back to perform the omitting ones such as "Lecture 10".

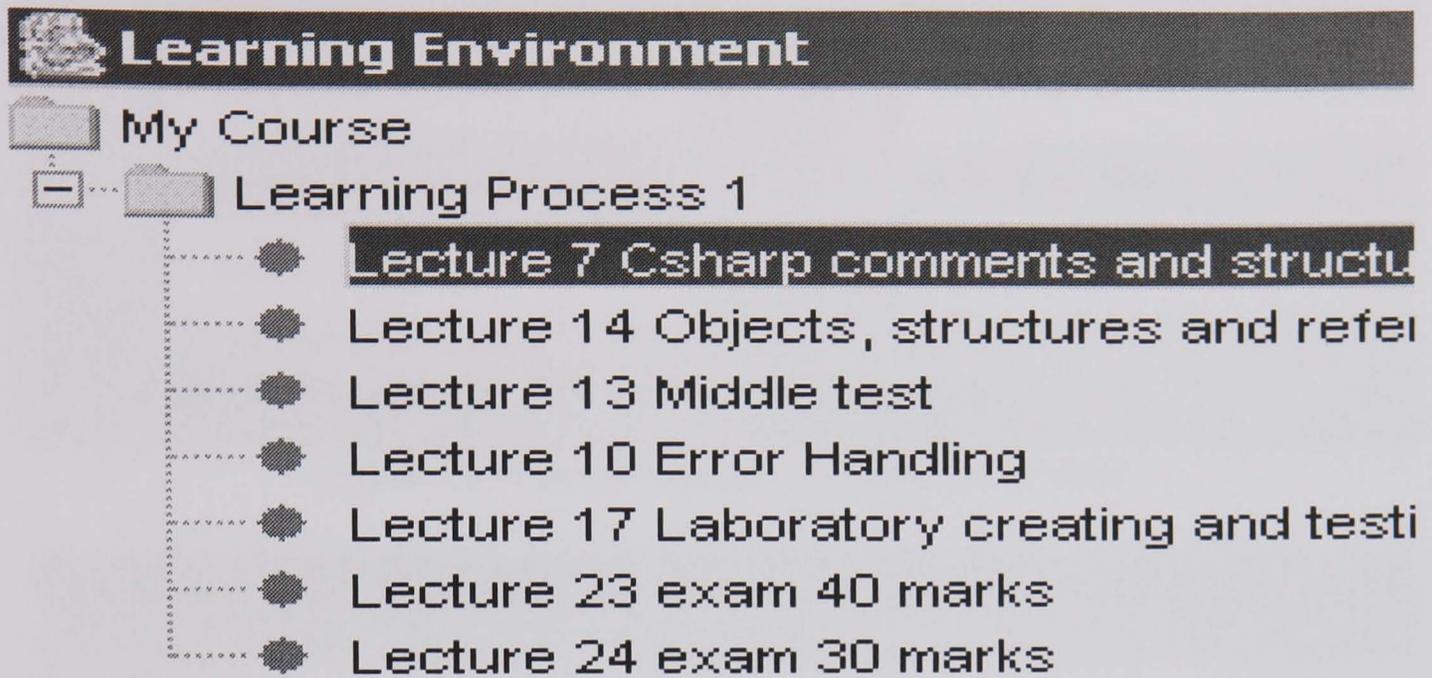


Figure 7.14 Learning Environment for Learners

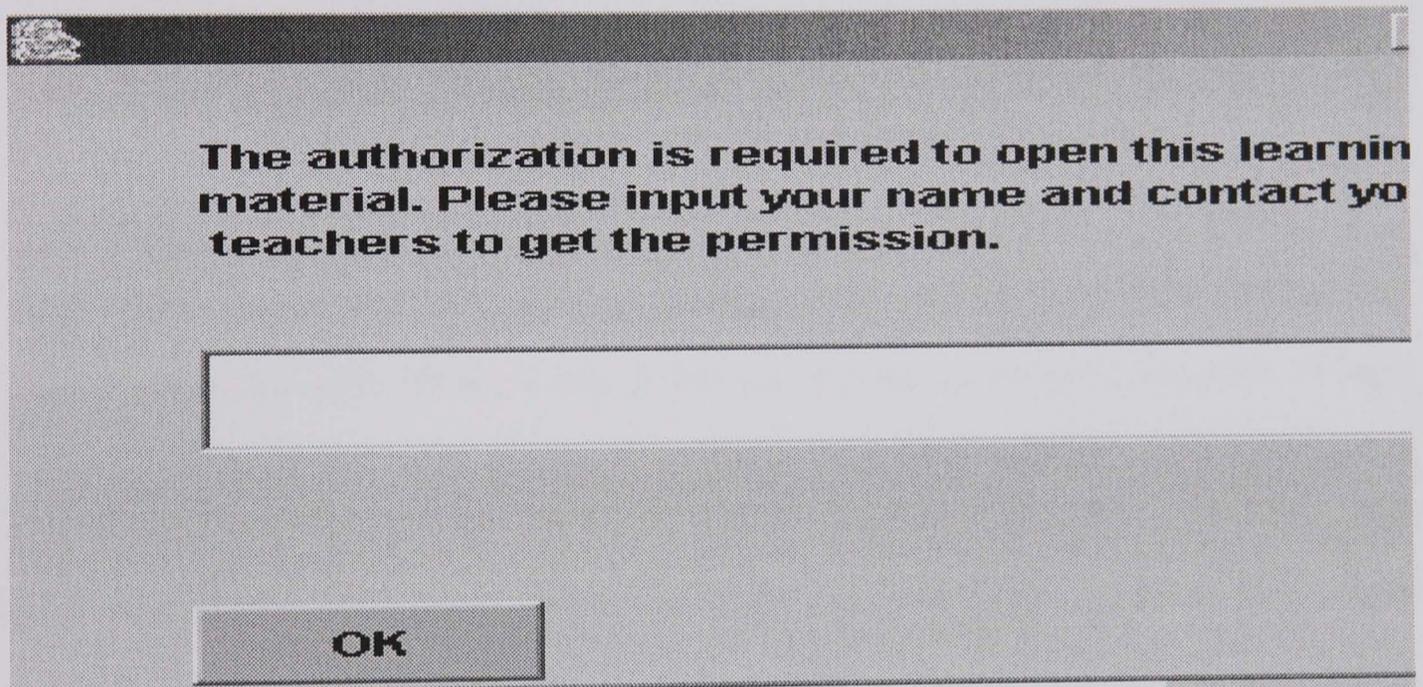


Figure 7.15 Dialog Box for Applying Permission

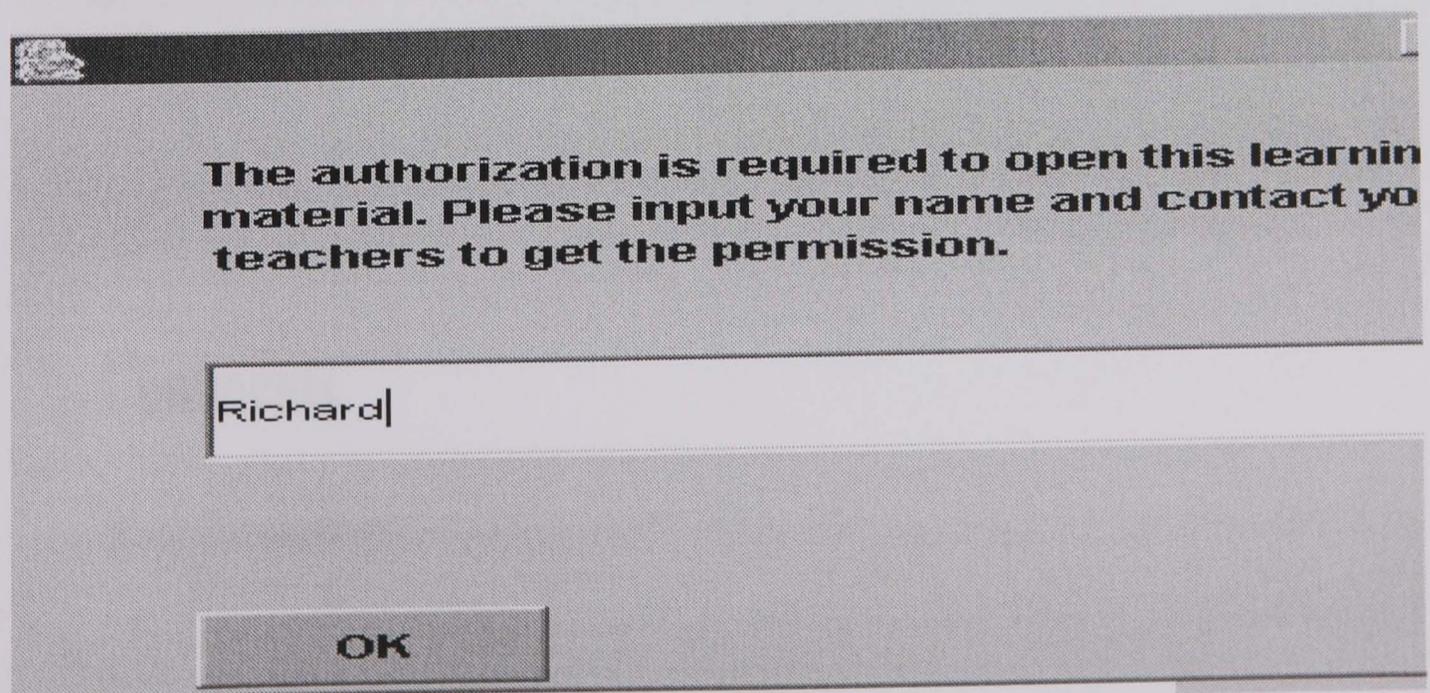


Figure 7.16 Input Students' Names

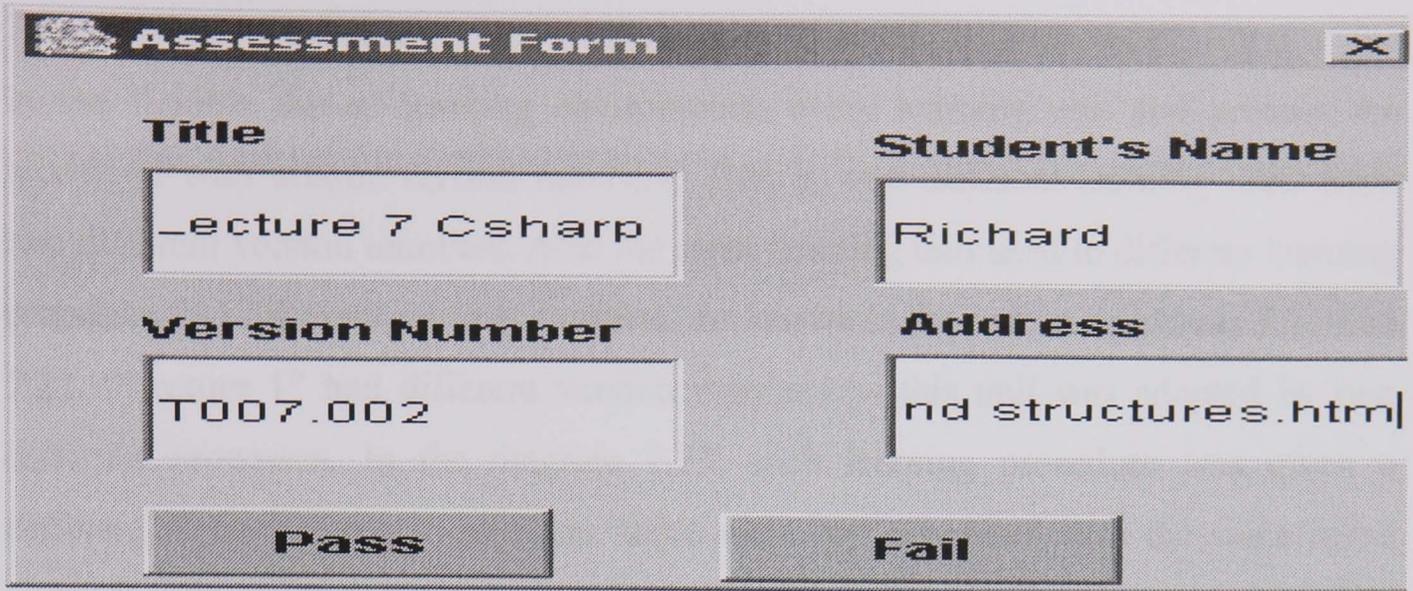


Figure 7.17 Present Students' Information to Staff

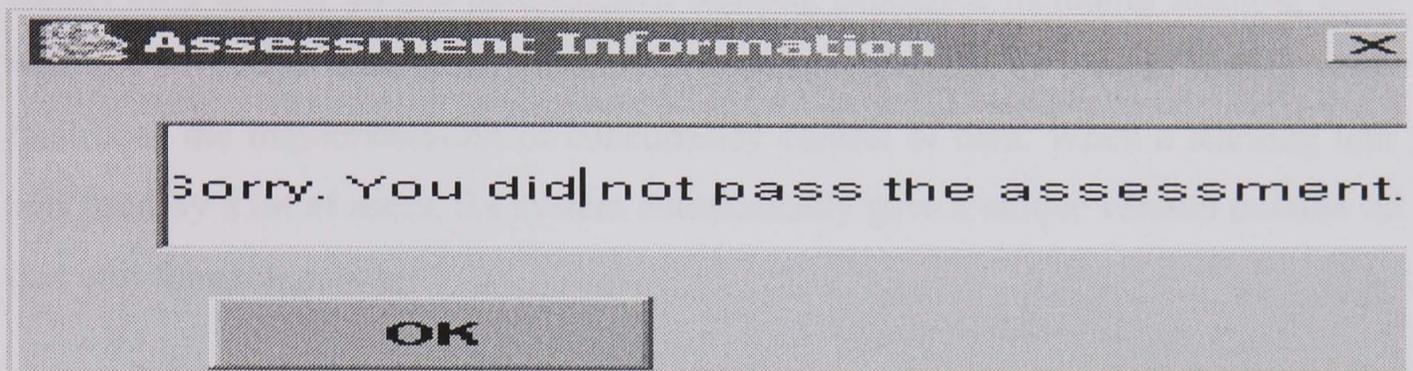


Figure 7.18 Feedbacks with No Permissions to Students

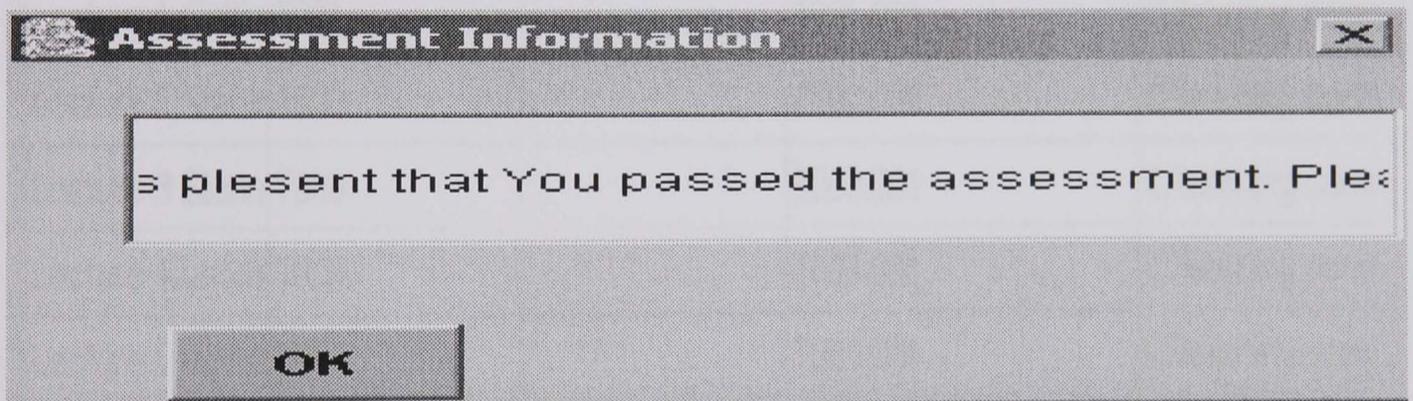
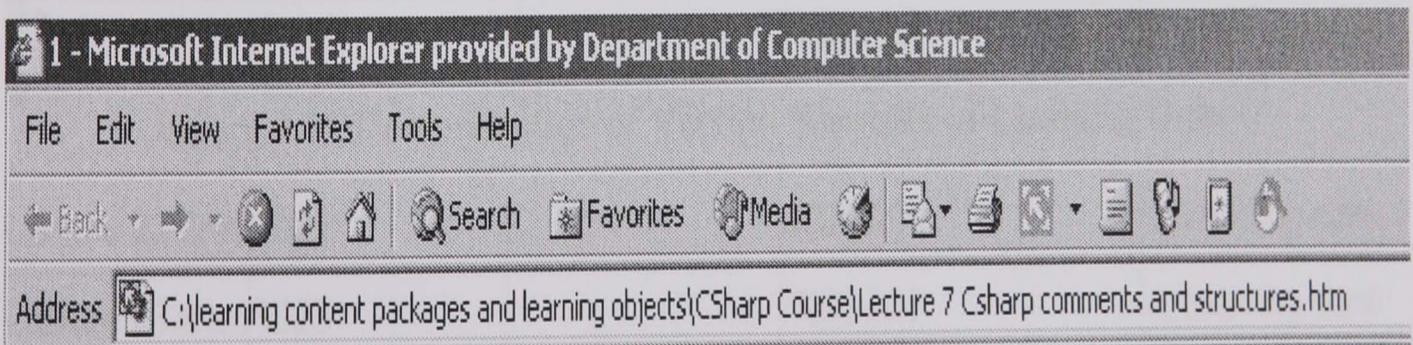


Figure 7.19 Feedbacks with Permissions to Students



# 1. Comments

==Block Comments==

When the C# compiler sees the `/*` sequence which means the start of a comment it says:

Figure 7.20 Open the Selected Units for Students

#### 7.4. Version Management and Concurrency Control

In the flexible virtual learning environment, every learning unit and process are identified with unique version numbers. That is, two different learning units have two different version numbers. Also the same learning unit used in different learning processes has different version numbers. As shown in the screen snapshots 7.21 and 7.22, "Lecture 1" had different version numbers as this unit was adopted by two different processes. In the diagram 7.23, each learning procedure was given a different identification. In addition, there were two processes with the same name and different versions, as they were built by different users who had different author names on a server. So the personalized learning processes including learning units will not be tied to machines. Furthermore, this mechanism of version management facilitates the implementation of concurrency control of data. When a learning unit was used by a lot of users, the system automatically gave a unique version number of this unit for each person.

TERMNAME	TERMIDENTIFI...	AUTHOROFTE...	TERMVERSIONNUMB...	TERMADDRE...
Lecture 1 Gettin	T001		T001.001	C:\learning conte
Lecture 2 Startir	T002		T002.001	C:\learning conte
Lecture 3 Storin	T003		T003.001	C:\learning conte
Lecture 4 Loops	T004		T004.001	C:\learning conte
Lecture 5 Metho	T005		T005.001	C:\learning conte
Lecture 6 Variak	T006		T006.001	C:\learning conte
Lecture 7 Cshar	T007		T007.001	C:\learning conte

Figure 7.21 Demonstration of Version Numbers of Learning Units I

Lecture 22 Crea	T022		T022.001	C:\learning cont
Lecture 23 exan	T023		T023.001	C:\learning cont
Lecture 24 exan	T024		T024.001	C:\learning cont
Lecture 25 exan	T025		T025.001	C:\learning cont
Lecture 1 Gettin	T001		T001.002	C:\learning cont
Lecture 2 Startir	T002		T002.002	C:\learning cont
Lecture 3 Storin	T003		T003.002	C:\learning cont

Figure 7.22 Demonstration of Version Numbers of Learning Units II

Search

	SCHEMANAME	SCHEMAIDENTIFI...	AUTHOROFSCHE...	SCHEMAVERSIONNUMB...	SCHEMAADDRE...	SC
1	wlp92000	S002		S002.001	C:/learning content p	
2	module 1	S003		S003.001	C:/learning content p	
3	module 1	S003		S003.002	C:/learning content p	

Figure 7.23 Demonstration of Version Numbers of Learning Processes

This chapter showed the implementation of the flexible VLE that can support the individualized creation and control of e-learning Web services [335]. Next, an assessment is to be completed to inspect whether the goals of this research are achieved or not.

## ***Chapter 8 Evaluation***

This chapter introduces the evaluation of this research. It is split into three parts. The first part presents a case study to readers, which systematically evaluates four e-learning tools for the practical requirements of targeted users in flexible e-learning: the flexible VLE, LAMS, RELOAD, and WebCT. The second one describes the results of this study. The final section shows the findings of this assessment, such as the advantages and limitations of our selected systems.

## **8.1. A Case Study**

The discussion on the theory of evaluation (e.g. a set of methods and the main same and distinctive features between them) was completed (appendix D), which provided the basis for the following experimental design.

### **8.1.1. Study Questions**

One central question to this case study is whether the selected four e-learning systems can support flexible e-learning as argued for in Chapter 1. Another key point is to find the limitations of the prototype. In order to respond to these questions, the evaluation focused on a set of elements in the usability of e-learning software, such as designer/learner models, learner control, teacher customisation, and pedagogy (section 8.1.3.).

### **8.1.2. Why Select Heuristic Evaluation Method**

The study questions involve the high-layer usability issues of e-learning systems such as whether a tool can support users to design learning processes with various orders and conditions (section 1.3.1. in Chapter 1 and sections 7.2. and 7.3. in Chapter 7). These demands can be met by evaluation using a method such as the heuristic approach (appendix D). Firstly, the heuristic method can provide high-level information to evaluators, and check any stage of a development process including the prototype. Secondly, this approach can provide a strong basis for the implementation of a reasonable assessment of system usability, because it always adopts a set of reliable and credible guidelines (e.g. heuristics) to design and execute an evaluation [336]. Thirdly, this method can encourage the development of a specific group of experts according to the particular demands of an assessment to gather data. Thus, the heuristic evaluation method can meet the requirements of the case study.

### **8.1.3. Evaluation Heuristics and Questions**

Nielsen's heuristics are regarded as the generic evaluation standards in the usability of software in various fields [336]. An example of these heuristics is "user control and freedom" that requires a tool to enable users to correct their behaviours when they choose system functions by mistake and to design navigation from the perspective of users. Besides, according to the study results of Nielsen, the heuristic "flexibility and efficiency of use" refers to a system that should facilitate the interaction for both inexperienced and experienced users.

Additionally, the standard “help users recognize, diagnose, and recover from errors” shows that a system should describe any error message in plain language not by programming codes. Then, the occurred problems need to be interpreted accurately, especially indicating these issues according to the ways of users’ thinking and behaving. Finally, the system should help users find their individualized solutions. This requires e-learning software to provide various instructional patterns to learners, such as problem based learning or other cognitive models. Students may represent their own ideas and study different solutions to problems, which facilitates learners in recovering from their cognitive errors and to achieve their educational aims.

Next, Squires and Preece designed a set of assessment criteria for e-learning systems, which are derived from the heuristics of Nielsen [336]. These evaluation criteria present the values of educational software in supporting online instruction based on different learning theories (Chapter 2). The diagram 8.1 shows the relationships between Nielsen’s heuristics and the criteria from Squires and Preece. In this evaluation, these criteria were regarded as the headers of the high-level assessment questions (section 8.2.). Some examples of the heuristics, criteria, and relevant questions are described as follows [336]:

- The criterion “learner control” from “user control and freedom” is expressed in two ways. One is whether the software supports learners to direct their own learning either individually or collaboratively. Another is whether the software supports learners to be instrumental in determining the manners and procedures of education.
- The criterion “teacher customisation” from “flexibility and efficiency of use” is analyzed in two areas. One is whether the software enables staff to build different instructional procedures according to the individualized needs of students. The other is whether the software enables staff to coordinate the instructional processes at runtime to adapt to the new requirements of learners.
- The criterion “pedagogy” from “help users recognize, diagnose, and recover from errors” is discussed in three points. The first one is whether the software supports a range of teaching styles, such as command, reciprocal, self-evaluation, guidance and counselling, self pace, and guided discovery patterns. The second one is whether the software supports two or more teaching styles mentioned above in a learning process. The final point is whether the software supports deep and/or surface learning approaches.

- The criterion “designer/learner models” deriving from “system status visibility” is described in three areas. The first one is whether the software enables users to obtain the required knowledge in their selecting instructional patterns. The second is whether the learning units are really integrated according to users’ requirements. The final one is whether the learning processes are really coordinated at runtime in users indicating orders and conditions.

	Cognitive authenticity			Contextual authenticity	
	Credibility	Complexity	Ownership	Collaboration	Curriculum
System status visibility	Feedback and designer/learner models	Navigation			
Match system/world	Cosmetic authenticity	Representations of the real world			
User control			Learner control	Shared responsibility	
Consistency		Symbolic representation		Consistent protocols	Subject content
Error prevention		Peripheral cognitive errors			
Recognition	Representational forms				
Flexibility	Multiple views/representations		Tailoring the interface		Teacher customisation
Aesthetic design		Superficial complexity			
Error recovery	Interaction flow	Pedagogical techniques	Metacognition		
Help/documentation		Learners’ support materials			

Figure 8.1 The Relationship between Heuristics and Learning Criteria

The selection principle of the criteria and relevant questions is that it should be helpful for presenting the main differences between the flexible e-learning tool and the other three educational systems: LAMS, RELOAD, and WebCT. In addition, these criteria and questions should demonstrate the limitations of the flexible VLE to readers. Furthermore, the selected evaluation criteria and questions in this case study are not used to test all of the practical requirements of students and staff. A lot of needs of teaching and learning have already been supported by existing e-learning systems, such as determining, authoring, publishing, discovery, sharing, and reuse of learning materials. The aim of this research is to provide the flexibility for users. So in this thesis, the main work has been to implement a range of teaching styles, supporting individualized educational processes, and flexibly controlling these processes during execution. The criteria and questions used in this case study were selected around these three tenets mentioned above.

#### **8.1.4. Choice of Computer Systems**

In this evaluation, LAMS, RELOAD, and WebCT were used as the computer systems for the case study. These systems had a set of features that were very relevant to the research subject, such as sequencing learning units (LAMS), describing the semantic information of units based on standards in terms of users' requirements (RELOAD), and developing and managing interactive Web courses (WebCT). The detailed information about these tools has been discussed in the section 3.5. of Chapter 3. Furthermore, the flexible VLE was used in this study.

#### **8.1.5. Participants**

There were ten evaluators in this case study: three professors, a tutor qualified with a PhD degree, and six PhD students. All of them have a good understanding about instruction. The professors have been doing academic jobs for 15 years and so have a lot of teaching experience. Also the others played the roles of teaching assistants and demonstrators for more than one year. Additionally, all of them have already used at least one e-learning tool. For example, the professors tried WebCT in their previous teaching activities. The others have the experience of using Blackboard in the University of Hull. Moreover, each participant has done their research in computer science for three years or more, which ensures that they have a good knowledge, background, experiences, and expertise on the development of a system.

#### **8.1.6. Handout**

There is a handout (appendix E) that was sent to evaluators at least three days before they did their assessments. Each handout consists of the goals of this case study, such as whether the four e-learning systems support flexible e-learning or not, and what the limitations of these tools in flexibility are. Furthermore, a set of definitions used in this evaluation were included in a handout, such as what the main differences among the selected tools are, what command teaching style is, what the individualized aggregation of learning units is, and what the personalized coordination of learning processes at runtime is. This is very helpful for users to get the meaning of the evaluation heuristics and questions used in the case study. When starting an assessment, the first task is to ask the participants whether they have a good understanding about their received handout. Here any query coming from the evaluators should be answered, which makes sure that they know what they were to do.

### **8.1.7. Running Scripts and Sessions**

Each e-learning system should be demonstrated with the same script (appendix F) that was designed before starting the case study, such as click the button “Open” or select the menu “File”. Furthermore, candidates should not be informed which tool is the implemented prototype. These ensure that all of systems can be evaluated on the same basis, as different participants received the same introduction to an e-learning tool. After the demonstration of each system, a heuristic evaluation session was held to answer the evaluators’ queries. Next, the subjects were asked to complete a set of questions about the system. Then, all of the above procedures were repeated to apply the testing to the other VLEs in the order: the Flexible VLE, LAMS, RELOAD, and WebCT. Finally, the participants were invited to give their comments to the whole process of this case study, such as commenting on the usefulness of this study and time taken.

### **8.1.8. Some Explanation of the Evaluation**

The case study focused on the typical usage of the systems not their general usage. In detail, the study concerned the usability issues in flexibility of the selected e-learning tools (e.g. learner control, teacher customisation, and pedagogy) rather than other functional areas (e.g. discovery of learning resources). This evaluation strategy was designed around the study questions (section 8.1.1.).

The handouts, instructions, and heuristic evaluation sessions were used in the context of the assessment, which provided the necessary information for the candidates to effectively complete their evaluations. In detail, the handout (appendix E) described the assessment aim for the participants, as well as the pedagogic terms (e.g. deep and surface learning) that were used in this case study. This helped users to know what they would do and to have a clear understanding of the heuristic questions. Next, by using the instructions (appendix F), it was explained to the candidates how to use the four e-learning systems to select learning units, aggregate these units to build learning processes, and control these processes. That is, the participants got the information about using these tools to design and complete their personal educational procedures. If users had not viewed the instructions, they would have to spend a lot of time in exploring the ways of using the systems by themselves. This could make people lose patience when doing the assessment, which would make it hard to ensure the quality of the case study. Furthermore, in the heuristic evaluation sessions, specific queries from users were answered, which helped people to understand the

tools clearly. Then, all of the experiences obtained by the candidates were used to complete the evaluation questions in order to check a set of usability issues (e.g. learner control, teacher customisation, and pedagogy) based on the work of Squires and Preece [336].

The principles for designing the inspection questions of this case study are now described. The involved issues in the evaluation are probably unfamiliar to participants as they have different research backgrounds. Thus, the questions should be authored to make it easy for the candidates to appreciate the root of the usability problems of these e-learning systems and to follow them step by step. Furthermore, the questions used in this assessment should be useful in developing the thinking of participants into the direction (the topics of this assessment), and required to ensure the validity of the case study. In addition, the more time that evaluators spend in doing an evaluation, the less patience that they may have. Here, the adopted questions should be able to cut the time taken by the participants as much as possible. It means that the questions should not involve the areas that are not related to the goals of this case study.

In this assessment, the questions in table 8.8 (e.g. “The evaluation shows the main differences among these e-learning systems”) were completed by the participants after finishing all of the questions in the tables from 8.1 to 8.7. That is, each candidate firstly did the evaluation on four systems in the same usability aspects (completing the same assessment questions from the tables 8.1 to 8.7) and finally evaluated the whole case study based on these answers. Here, through responding to the questions in the tables from 8.1 to 8.7 for each system, users got the data about what features in flexibility one e-learning tool can support and the others can not, as well as the restrictions of the systems. Then, the general judgements to this case study were given by the evaluators. This method is very helpful for the participants to give the valuable comments to the whole evaluation.

## **8.2. Results**

During this case study, each evaluator checked the usability issues of all four systems. Furthermore, different participants should use the same evaluation heuristics and questions from Squires and Preece to assess any e-learning tool. This can identify the differences and limitations to these systems. For each e-learning software, a candidate filled in a copy of the heuristics and questions and finally identified

themselves with his/her names and/or titles. Next, all of the copies were collected and the relevant data was processed in the way of a percentage. An example of this is if nine out of ten people agreed or strongly agreed an idea, “90% (A)” would be appeared behind the related question. Also “70% (D)” refers to seven out of ten participants disagreed a conclusion, and “10% (M)” shows that only one evaluator selected “Maybe” on a question. Then, the results obtained from this case study were divided into two parts. One was used to test the usability issues of four e-learning systems; another was to describe the comments to the whole assessment. Finally, the summarized representation of the data was completed in the following sections.

### 8.2.1. Designer/Learner Models

Seven out of ten evaluators (70%) supported the statement that the flexible VLE was helpful for them to get the required knowledge in their personal learning ways. 80% thought that LAMS was hard in helping users acquire the preferred knowledge over their individual patterns. 70% regarded RELOAD and WebCT to be the same as LAMS in this aspect.

Questions	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
The software helps me to obtain the required knowledge in my own way.	70% (A) 10%(M) 20% (D)	10% (A) 10% (M) 80% (D)	20% (A) 10% (M) 70% (D)	20% (A) 10% (M) 70% (D)
The learning units are really integrated in my own way.	90% (A) 10% (D)	20% (A) 10% (M) 70% (D)	10% (A) 20% (M) 70% (D)	10% (A) 10% (M) 80% (D)
The learning processes are really coordinated in my own way at their runtime.	90% (A) 10% (D)	20% (A) 10% (M) 70% (D)	10% (A) 10% (M) 80% (D)	20% (A) 10% (M) 70% (D)

Table 8.1 Designer/Learner Models

Nine out of ten users (90%) recognized that the learning units can be aggregated according to their own ways by using the flexible VLE, while 70% on LAMS and RELOAD and 80% on WebCT thought that these three systems did not.

90% agreed that the flexible VLE supported the coordination of a learning process at runtime according to their own requirements; 70% regarded that LAMS and WebCT did not; and 80% thought RELOAD did not have this ability.

### 8.2.2. Representations of the Real World

Eight out of ten participants (80%) supported that the flexible VLE simulated instructional procedures in a similar way as the traditional education, while 70% on LAMS and WebCT and 80% on RELOAD thought that these three tools did not reach this capability.

70% recognized that the flexible VLE and WebCT provided various constructed microworlds that supported users' cognitive mechanisms in the real world. For LAMS and RELOAD, 70% thought that they did not.

90% supported that the flexible VLE represented the semantic information of learning units and processes in terms of the demands of learners and/or staff, while 70% on LAMS and RELOAD and 80% on WebCT regarded that they did not.

Questions	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
The software simulates instructional procedures in a similar way as the traditional education.	80% (A) 20% (D)	10% (A) 20% (M) 70% (D)	10% (A) 10% (M) 80% (D)	20% (A) 10% (M) 70% (D)
The software provides various constructed microworlds that can support users' cognitive mechanisms in the real world, such as supporting a learner to exercise powerful ideas.	70% (A) 10% (M) 20% (D)	20% (A) 10% (M) 70% (D)	20% (A) 10% (M) 70% (D)	70% (A) 10% (M) 20% (D)
The software supports the description of semantic information of learning units and processes in terms of the demands of learners and/or staff.	90% (A) 10% (M)	20% (A) 10% (M) 70% (D)	20% (A) 10% (M) 70% (D)	10% (A) 10% (M) 80% (D)

Table 8.2 Representations of the Real World

### 8.2.3. Learner Control

Nine out of ten evaluators (90%) agreed that the flexible VLE supported learners to direct their own learning either individually or collaboratively, while 70% on LAMS, RELOAD, and WebCT regarded that these three tools did not.

80% recognized that the flexible VLE supported learners to be instrumental in determining the manners and procedures of education, while 80% on LAMS and 70% on RELOAD and WebCT thought that the three systems did not.

Questions	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
The software supports learners to direct their own learning either individually or collaboratively.	90% (A) 10% (M)	10% (A) 20% (M) 70% (D)	10% (A) 20% (M) 70% (D)	30% (A) 70% (D)
The software supports learners to be instrumental in determining the manners and procedures of education.	80% (A) 20% (M)	10% (A) 10% (M) 80% (D)	20% (A) 10% (M) 70% (D)	20% (A) 10% (M) 70% (D)

Table 8.3 Learner Control

#### 8.2.4. Multiple Views/Representations

Seven out of ten participants (70%) supported that the flexible VLE, LAMS, and WebCT provided a variety of representations of learning units in an integrated learning environment. Also 80% on RELOAD thought that the product had the same ability.

70% regarded that the flexible VLE, LAMS, and RELOAD did not support different strategies (e.g. serialist and holistic learners) for learning. 80% recognized that WebCT provided a set of learning strategies to students and teachers.

Questions	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
The software provides a variety of representations of learning units in an integrated learning environment, such as selecting a test with an HTML format.	70% (A) 10% (M) 20% (D)	70% (A) 30% (D)	80% (A) 20% (D)	70% (A) 30% (D)
The software supports different strategies for learning, such as serialist and holistic learners.	20% (A) 10% (M) 70% (D)	10% (A) 20% (M) 70% (D)	20% (A) 10% (M) 70% (D)	80% (A) 20% (M)

Table 8.4 Multi Views/Representations

### 8.2.5. Teacher Customisation

Eight out of ten candidates (80%) regarded that the flexible VLE supported staff to build different instructional procedures according to the individualized needs of students. 70% on LAMS and WebCT and 80% on RELOAD thought that these three systems lacked of this capability.

Questions	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
The software supports staff to build different instructional procedures according to the individualized needs of students.	80% (A) 20% (D)	20% (A) 10% (M) 70% (D)	20% (M) 80% (D)	10% (A) 20% (M) 70% (D)
The software supports staff to coordinate the instructional processes at runtime to adapt the new requirements of learners.	100% (A)	20% (A) 10% (M) 70% (D)	30% (A) 70% (D)	10% (A) 90% (D)

Table 8.5 Teacher Customisation

Ten out of ten users (100%) recognized that the flexible VLE supported staff to coordinate the instructional processes at runtime to meet the new requirements of learners. 70% on LAMS and RELOAD and 90% on WebCT agreed that these systems did not.

### 8.2.6. Interaction Flow

Ten out of ten evaluators (100%) said that the flexible VLE provided feedback or hints to learners about their personalized operations on learning units and processes. 80% on LAMS and RELOAD and 70% on WebCT thought that the three tools did not.

100% recognized that the flexible VLE supported “bolt-on” tutorial orders, such as locked an online exam PDF file. 80% regarded that LAMS and WebCT did not have this ability, and 70% thought RELOAD also did not.

Questions	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
The software provides feedback or hints to learners about their personalized operations on learning units and processes,	100% (A)	10% (A) 10% (M) 80% (D)	20% (M) 80% (D)	10% (A) 20% (M) 70% (D)

such as whether a learner can open a lecture or not.				
The software supports “bolt-on” tutorial orders, such as lock an online exam PDF file.	100% (A)	10% (A) 10% (M) 80% (D)	20% (A) 10% (M) 70% (D)	10% (A) 10% (M) 80% (D)

Table 8.6 Interaction Flow

### 8.2.7. Pedagogical Techniques and Metacognition

Seven out of ten participants (70%) agreed that the flexible VLE supported a range of teaching styles, such as command, self pace, and guided discovery patterns. 70% thought that LAMS and WebCT did not reach this requirement, and 80% regarded that RELOAD also did not.

Questions	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
The software supports a range of teaching styles, such as command, reciprocal, self-evaluation, guidance and counselling, self pace, and guided discovery patterns in education.	70% (A) 10% (M) 20% (D)	20% (A) 10% (M) 70% (D)	10% (A) 10% (M) 80% (D)	20% (A) 10% (M) 70% (D)
The software supports two or more teaching styles mentioned above in a learning process.	30% (A) 70% (D)	70% (A) 20% (M) 10% (D)	20% (A) 10% (M) 70% (D)	10% (A) 10% (M) 80% (D)
The software supports deep and surface learning approaches.	20% (A) 10% (M) 70% (D)	20% (A) 10% (M) 70% (D)	30% (A) 70% (D)	20% (M) 80% (D)

Table 8.7 Pedagogical Techniques and Metacognition

70% recognized the flexible VLE and RELOAD did not support two or more teaching styles mentioned above in a learning process, and 80% said that WebCT also did not. 70% agreed that LAMS had this capability.

70% regarded that the flexible VLE, LAMS, and RELOAD did not support deep and surface learning. 80% said that WebCT also did not.

### 8.2.8. Comments to the Evaluation

As shown in this table, nine out of ten evaluators (90%) felt that the case study showed the main differences, the different degrees in supporting flexible e-learning, and the limitations on the four e-learning systems. Eight out of ten candidates (80%) agreed that the data can be analysed statistically and presented as graphs. Besides, four participants (40%) spent one hour to complete their assessments; 30% did the testing with one hour and five minutes; and 30% in one hour and 10 minutes.

Questions	Results
The evaluation shows the main differences among these e-learning systems.	90% (A) 10% (M)
The evaluation shows the different degrees of these systems in supporting flexible e-learning.	90% (A) 10% (M)
The evaluation shows the limitations of these systems.	90% (A) 10% (M)
The evaluation results are usable in statistics ways, such as presenting the data in percentage method in diagrams or tables.	80% (A) 10% (M) 10% (D)
How long does the evaluation take?	40% (1 Hour) 30% (1 Hour 5 Minutes) 30% (1 Hour 10 Minutes)

Table 8.8 Comments to the Evaluation

### 8.3. Findings

Based on the results of this case study, the conclusions are summarized and presented to readers. This was divided into two areas. One was that whether this case study was valuable or not, another was that whether the assessment represented the advantages and limitations of the flexible VLE in comparison with LAMS, RELOAD, and WebCT.

#### 8.3.1. The Case Study

According to the data presented by the table 8.8, it was agreed that the main differences in flexibility about the four tools were found by the candidates. Also the responses in this table showed that the participants thought the systems to be in different degrees in supporting flexible e-learning. Furthermore, the limitations of the

tools were captured by the participants in this case study. In sum, it was regarded that the evaluation was completed satisfactorily.

### 8.3.2. Comparison between Four Systems

The findings of the usability examination of these tools are presented to readers from two points of view: advantages and limitations. Compared with LAMS, RELOAD, and WebCT, the benefits of the flexible VLE are represented in the following paragraphs. Each part identified with bold items explained the relevant contents in table 8.9 based on the data of this evaluation (section 8.2.).

- In the area of “**Designer/Learner Models**”, the flexible VLE was useful in users’ getting their required knowledge in their individualized patterns and the other three systems were not (section 8.2.1.). The responses supported the notion that the flexible VLE had the ability to integrate the learning units according to the practical requirements of students and staff, and other software did not. The flexible VLE was suitable for modifying learning processes at runtime according to the new demands of users, whilst others did not. All of the analysis showed that the flexible VLE allowed users to undertake their education using different learner models, which provided much more flexibility for users than the other three systems.
- The usability of the flexible VLE in the field of “**Representations of the Real World**” was that: did an education process in a traditional way on the Internet, built different personalized instructional environments to meet users’ actual cognitive patterns, and described the semantic information of learning units and processes in terms of users’ individualized needs (section 8.2.2.). LAMS and RELOAD did not have these abilities, and WebCT only supported the middle one. In summary, the flexible VLE provided much more powerful abilities than others in meeting various factors in education.
- The features of the flexible VLE represented in the aspect of “**Learner Control**” were not achieved by LAMS, RELOAD, and WebCT (section 8.2.3.). An example of this was that the flexible VLE allowed learners to individually or collaboratively control their learning procedures. Also the system gave learners the rights in determining the ways and processes of instruction. Both of the evidence presented that the flexible VLE implemented the higher learner control on learning processes than the other three tools.
- The usability of the flexible VLE in the point of “**Teacher Customisation**” was that the prototype supported teachers to create personalized learning procedures

for learners and to coordinate a process at runtime to meet the new requirements of a learner (section 8.2.5.). LAMS, RELOAD, and WebCT did not accomplish these tasks. The flexible VLE gave staff much more freedom than other tools in designing and controlling electronic learning processes.

- In the aspect of “**Interaction Flow**”, the flexible VLE informed learners about whether they were allowed to do their personalized operations on learning units and processes, and implemented “bolt-on” tutorial orders such as locked a unit (section 8.2.6.). LAMS, RELOAD, and WebCT did not meet these demands. It means that the flexible VLE provided more and stronger functions than the other three systems in controlling learning resources.
- As shown in the area of “**Pedagogical Techniques and Metacognition**”, the flexible VLE supported the teaching styles of command, reciprocal, self-evaluation, guidance and counselling, self pace, and guided discovery (section 8.2.7.). LAMS, RELOAD, and WebCT did not have this capability. This made it much easier for the flexible VLE to meet users’ demands in pedagogy than other systems.

Heuristics	E-Learning Tools			
	The Flexible VLE	LAMS	RELOAD	WebCT
<b>Designer/Learner Models</b>	Support	No	No	No
<b>Representations of the Real World</b>	Support	No	No	Support users’ cognitive mechanisms in the real world
<b>Learner Control</b>	Support	No	No	No
<b>Multiple Views /Representations</b>	Support a variety of description formats.	Support a variety of description formats.	Support a variety of description formats.	Support
<b>Teacher Customisation</b>	Support	No	No	No
<b>Interaction Flow</b>	Support	No	No	No
<b>Pedagogical Techniques and Metacognition</b>	Support a set of teaching styles: command, reciprocal, self-evaluation, guidance and counselling, self pace, and	Support two or more teaching styles in a learning process.	No	No

	guided discovery.			
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Table 8.9 Findings of the Evaluation

The restrictions of the flexible VLE are listed as follows:

- In “**Multiple Views/Representations**”, the flexible VLE did not support different educational strategies such as serialist and holistic learners (section 8.2.4.).
- In the area of “**Pedagogical Techniques and Metacognition**”, the flexible VLE did not contain two or more teaching styles (e.g. command, self pace, and guided discovery) in a learning process (section 8.2.7.). Furthermore, the software did not implement deep and surface learning approaches.

The above sections described a set of discoveries derived from the case study. The advantages of the flexible VLE showed that the flexibility in the aggregation and control of online learning services and applications was implemented. This can provide a lot of facilitation for users to do their instruction on the Web. In addition, the restrictions of the prototype indicated the further tasks that this tool should improve.

In this chapter, an assessment on this research has been completed. Next, the conclusions about this thesis will be represented.

## ***Chapter 9 Conclusions***

In this chapter, a refined summary of this research is given in three sections. The first section represents the research contributions. In the second section, reflections on the process and methodology are shown to readers. The final section presents some areas worthy of further work.

### **9.1. Thesis Contributions**

The research achievement is that the flexible management of e-learning Web services and applications in terms of the practical requirements of students and staff is implemented. This accomplishment greatly facilitates users to do their individualized education on the Web. The detailed efforts can be described as follows:

- This research can support a range of teaching styles. In instruction, different patterns are used by users to meet their individualized needs. Based on a schema-driven approach using the Semantic Web concepts, a flexible virtual learning environment was implemented. This tool can allow students and/or staff to design and coordinate their learning procedures at the layer of pedagogy. For example, the tool can support staff to decide instructional aims, content, and processes to implement the command teaching manner. Furthermore, the system can allow learners to control every thing in their learning by themselves. Thus, a range of teaching manners can be supported in terms of the personalized demands of users.
- This research can support individualized educational processes. Before starting teaching and learning, learners and staff need to design instructional processes with units according to their particular requirements. Through integrating the Semantic Web and other computer technologies, the schema-driven approach and the flexible VLE were produced. This tool can aggregate the selected learning units in personalized orders and conditions designed by students and/or instructors. That is, the preferred learning units can be chosen, and the indicated sequences can be built.
- This research can support the individualized control of educational procedures during execution. During running instruction, teachers and learners wish to automatically coordinate the processes according to the changes of the situations of users. In the research, the flexible VLE can support students to jump back or front to any indicated learning units through the discussion with staff during executing learning processes. That is, the links between learning units can be changed at runtime to meet users' individual demands, which can support users to flexibly control the execution procedures of e-learning Web services and applications.

### **9.2. Reflection on the Process**

In the world of education, there are quite large individual differences such as having different background knowledge, operating learning content in different ways,

needing different supervisory methods, learning in different schedules, and obtaining different learning results. It means that different learning theories, instructional styles, and varieties of learning procedures should be supported by e-learning systems. The research focused on this area and the achievements were described in the above section. One of the main limitations of the research is that not all of educational styles were supported. Another main restriction is that two or more styles were not supported in a learning procedure. The possible solution for these limitations is to build a template for each style, in which students and/or educators can design their interesting instructional procedures according to the features of a style. Then, the connection between templates should be established for people to move from one style to another.

### **9.3. Reflection on the Methodology**

In the area of computer science, technologies are developed very quickly and standards are produced to define and specify topics at the layer of theory and/or technique. These would bring more powerful functions to users. So one of the key problem is that how to make systems and applications to go with the new standards and technologies. In the thesis, I designed and implemented a schema-driven approach and a flexible virtual learning environment. Both of them are built based on a set of widely-used standards and technologies. With the development of standards and technologies, a lot of more advanced abilities could be supported to meet more actual requirements of users in e-learning. It means that the functions provided by existing e-learning systems need to be updated. So the question is how to aggregate the emerged standards and technologies into existing e-learning systems, especially the flexible virtual learning environment. The new standards and technologies could be simply assembled into existing systems as a set of modular units. Although it is difficult to achieve this, it is still a valuable topic for consideration. If I could implement the seamless connection between the implemented tool and new standards and technologies, it could largely facilitate the development of systems and applications. Especially if all of software on the internet could do it as mentioned above, it could bring huge benefits to institutions, enterprises, and individuals.

### **9.4. Further Work**

Although I completed a lot of research during this PhD programme, there are still some worthy research areas that could be done in the future. These further works were described as follows:

- In this research, I designed a schema-driven approach based on the Semantic Web and other computer technologies. Next, a flexible virtual learning environment was implemented over this approach. Then, a case study was completed by using the method of heuristic evaluation. The following step could be importing this tool into a practical use environment in which educators and learners would adopt the system to complete their instruction. The tool would face an actual inspection, which may lead to further refinement of the tool.
- The research focuses on implementing a flexible virtual learning environment to map a range of requirements of students and staff. It omits the communication and interaction based on different standards, such as UK LOM Core, DCMI, and EML (section 3.4. of Chapter 3). As e-learning systems are developed over different protocols, it is valuable to support the translation of these protocols between varieties of educational software. All of e-learning Web services and applications deployed on the Internet would be shared and used by users in different computing environments.
- The schema-driven approach implemented in this research is not limited to the e-learning area. This approach could be used in other fields, which could be another valuable work of further research. In the thesis, the approach was designed to support the semantic description and flexible control of e-learning Web services and applications. It could be also worthy to adapt this method into other Web services, such as e-government, e-business, or digital library. In these fields, the approach could be considered to be a way representing the semantic information of Web services and applications according to users' individual demands, such as the titles, publishers, and versions of books in a digital library. In addition, the Web services and applications in the fields could be authored and managed by using this method, such as sequencing the steps in an office process of a government department.

This chapter has summarized the acquisition in doing this research and the future work. The following content of the thesis is the references and appendixes.

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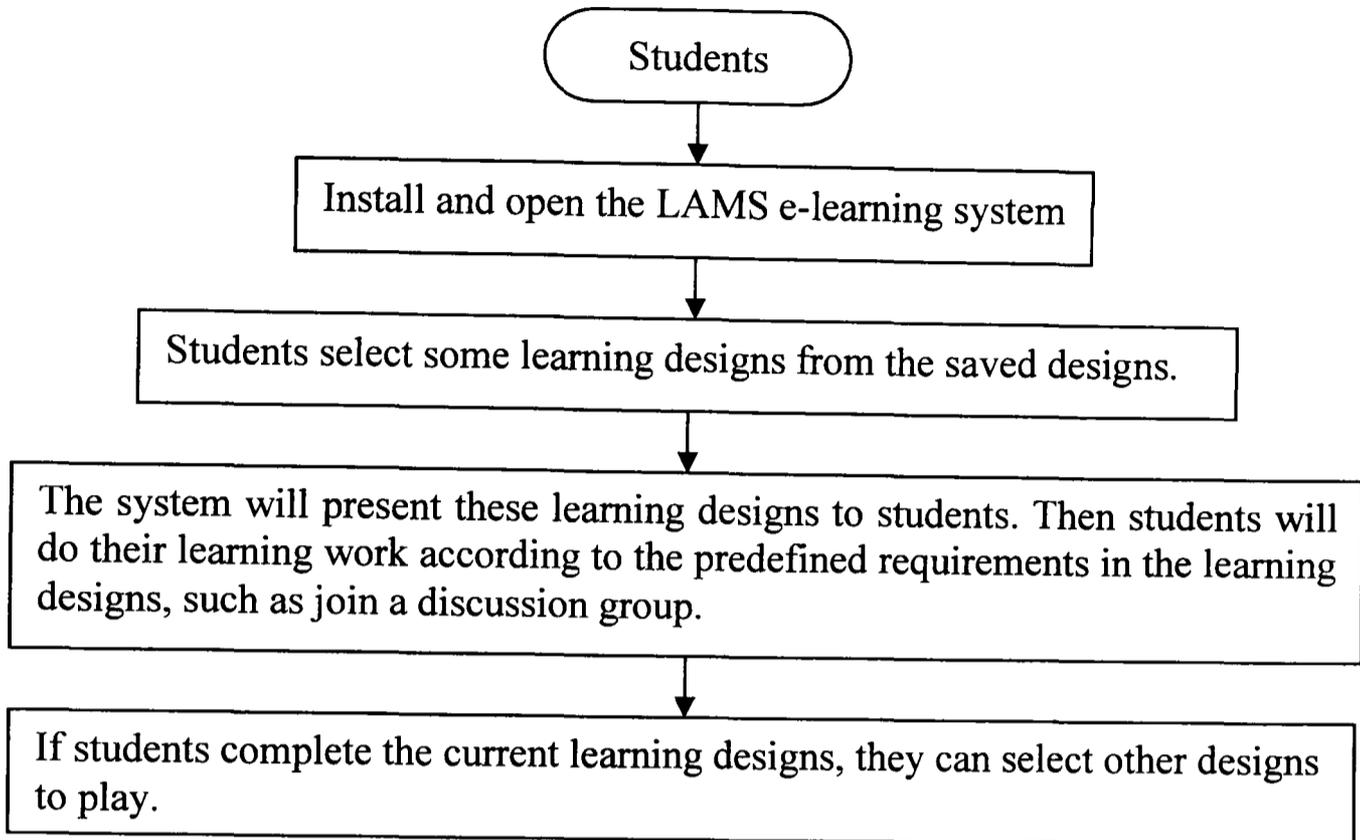
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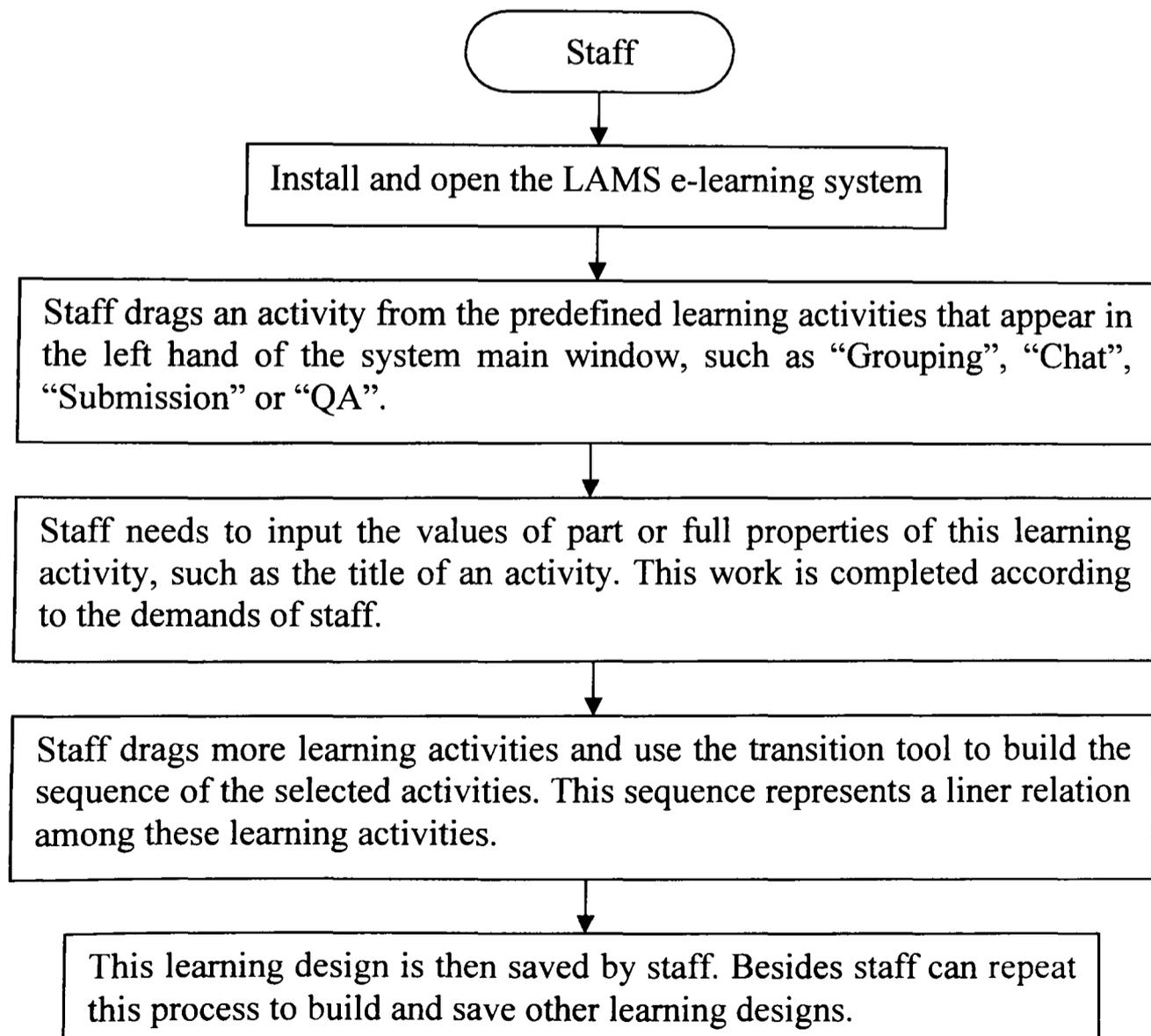
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## *Appendix A---List of Flowcharts*

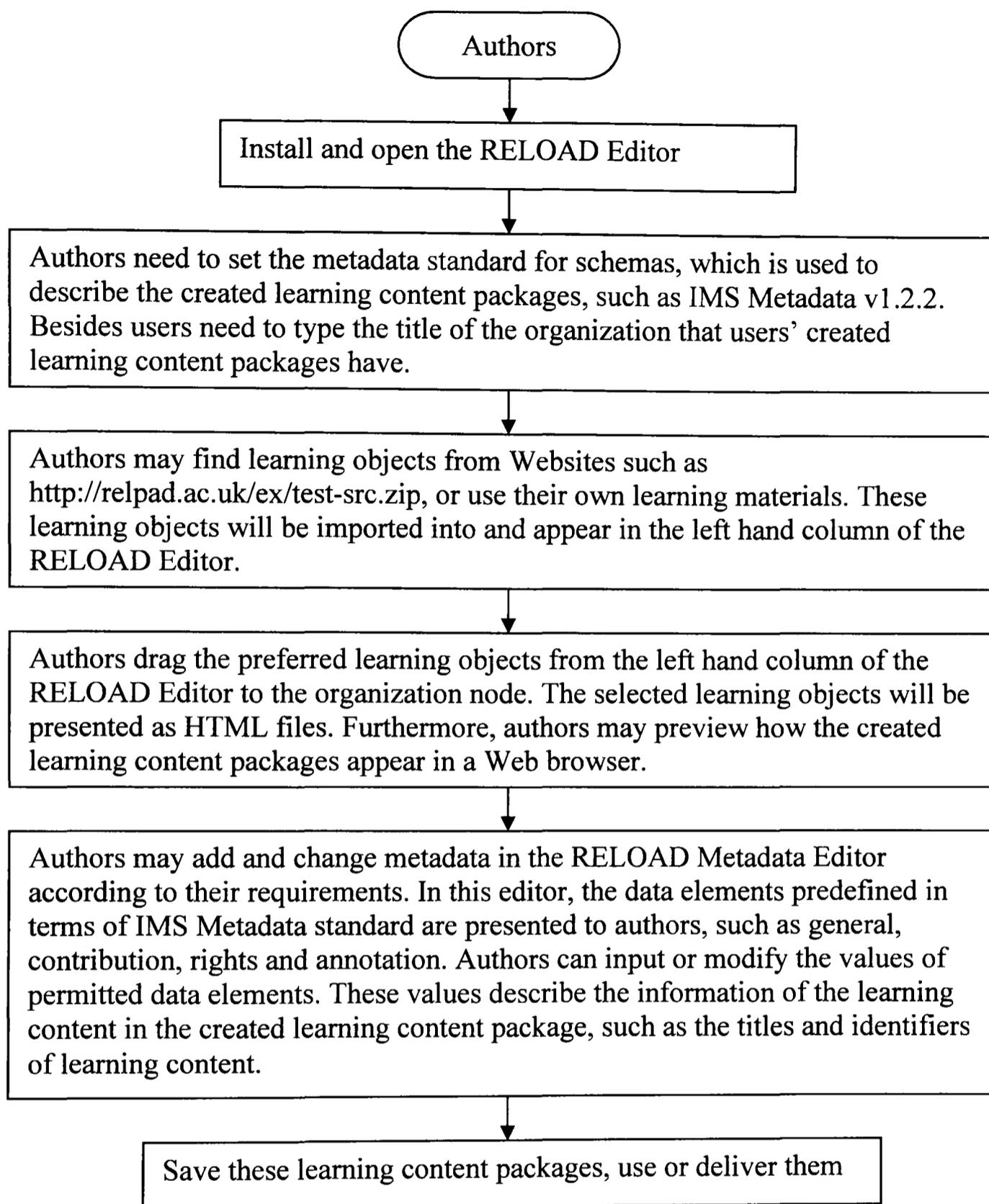
### **1. Flowchart 3.1 the Flowchart of LAMS for Students**



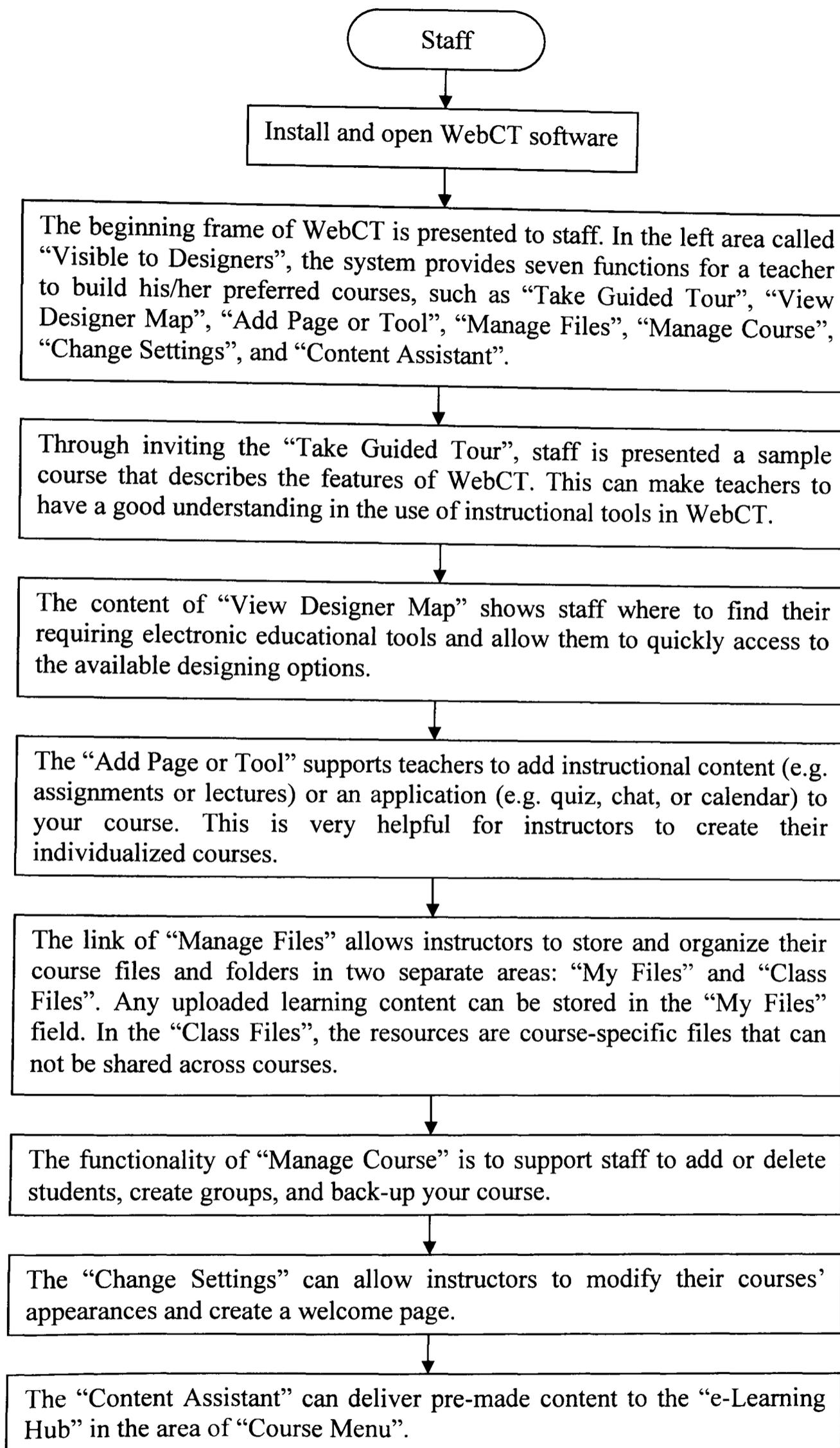
### **2. Flowchart 3.2 the Flowchart of LAMS for Staff**



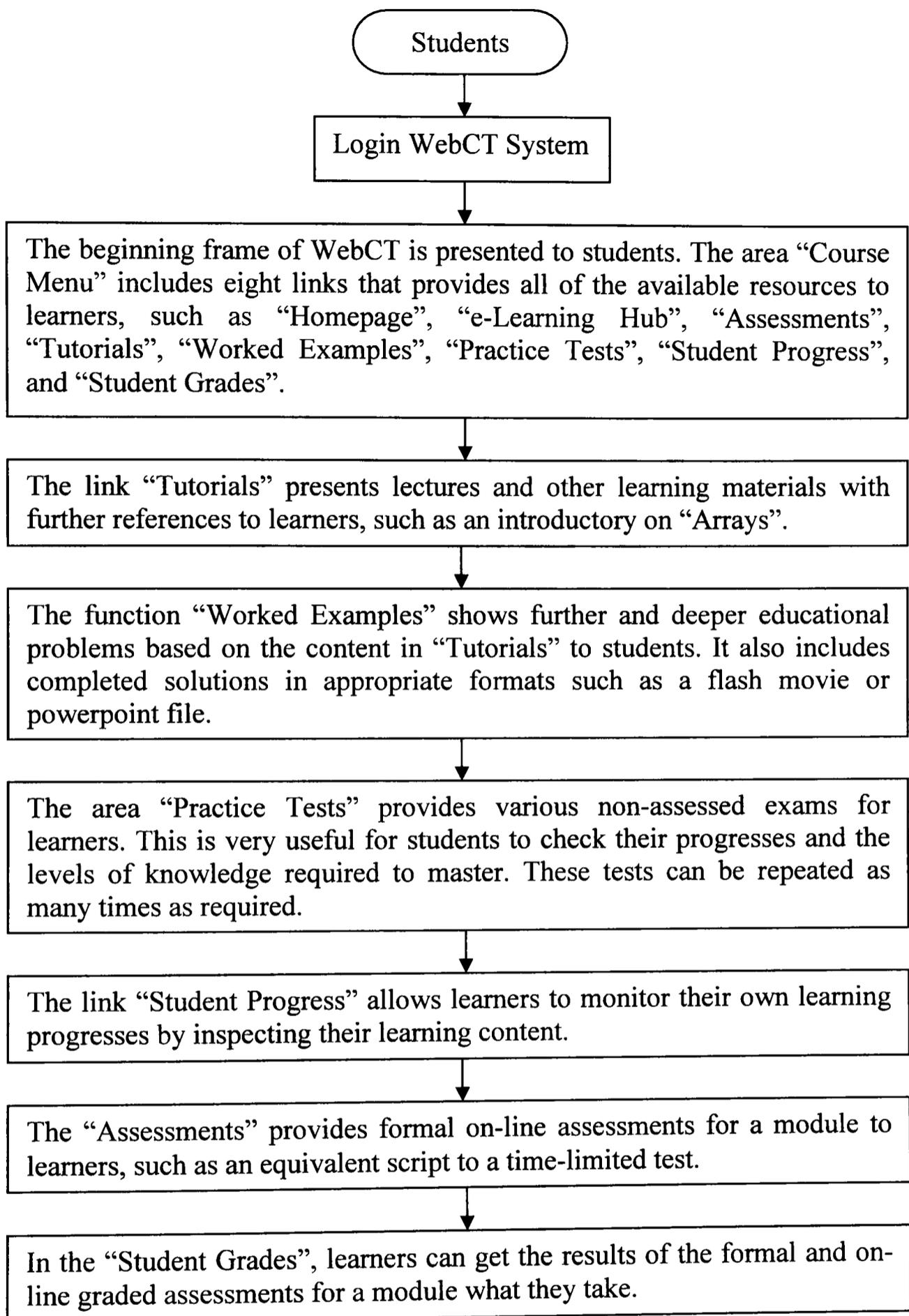
### 3. Flowchart 3.3 the Flowchart of RELOAD



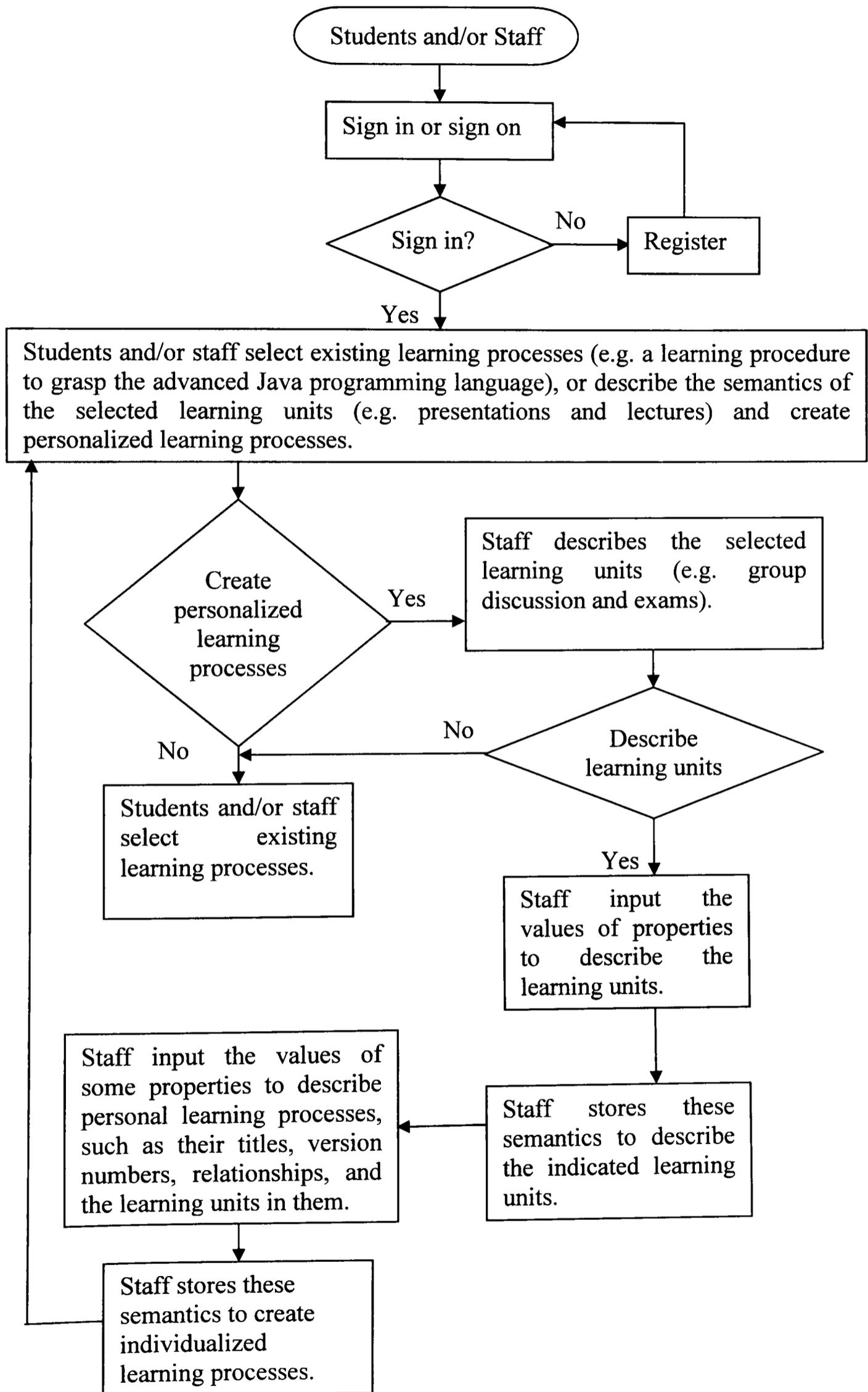
#### 4. Flowchart 3.4 the Flowchart of WebCT for Staff



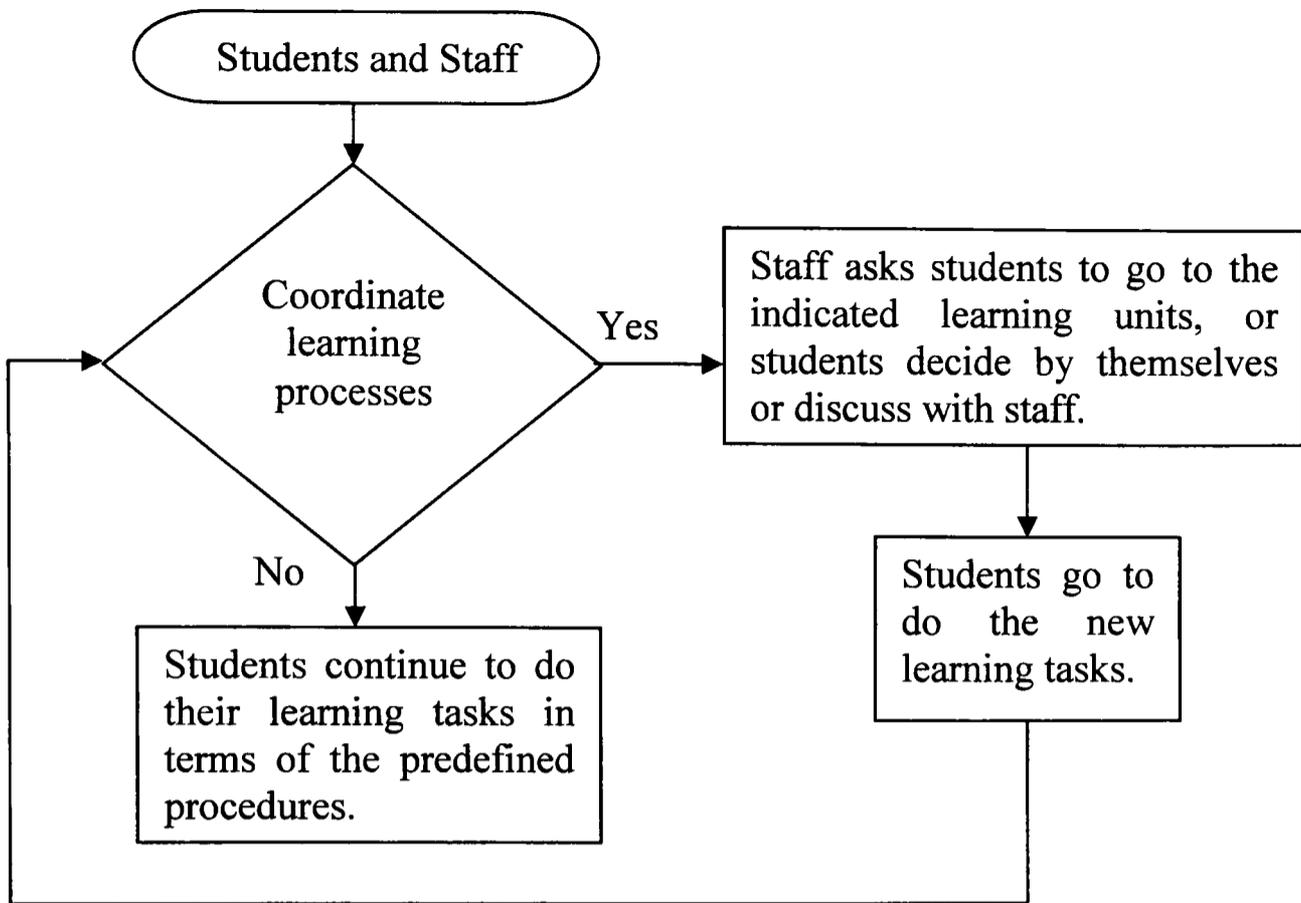
## 5. Flowchart 3.5 the Flowchart of WebCT for Students



6. Flowchart 4.1 the Flowchart for Students and/or Staff to Create Individualized Learning Processes



7. **Flowchart 4.2 the Flowchart of Personalized Control of Learning Processes**



**8. Flowchart 6.1 the Flowchart of the Creation of Terms for Individualized Learning Units**

The Beginning Web Page

Username   
 Password

(Authors here include students and/or staff. Also, new authors need to click the button “Sign On” to register, and old users may directly enter the system through clicking “Sign In”.)

Users’ Registration Form for Authors (Web page)

First Name  Username   
 Last Name  Password   
 (Password: Year-Month-Four free letters or digits, YYYY-MM-FFFF)  
 Road  City   
 Country  Email   
 (The special demands for authors will be presented as follows, such as achievements.)  
 Achievements   
 (Users need to provide the achievements they obtained, such as certificates and publications.)

(When users fill in this form, they may click the button “Submit” to register. Then a dialog will be launched to users, which tells users there will be an email to them in a few days about whether their registrations are accepted or not. Through clicking “Cancel”, users can return to the beginning Web page without registrations.)

Thank you for your registration. We will send an email to you about whether your registration is successful or not.

After Registration, Click “Sign In”, Enter “Using Existing Learning Processes”

The schema drive and control platform will capture all existing learning activities’ titles from vocabulary databases, and display them to students. When students choose a learning activity or process and click the button “Run”, the system will play it from \* automatically (\* is shown in the following). If students do not find any suitable learning process, they may click the button “Create” and return to the Web page “Creating Special Learning Activities” to create their personal learning activities. If students click the button “Log Off”, they will return to the beginning Web page.

Or Creating Special Learning Processes

Course

<input checked="" type="checkbox"/> Course 1	<input type="checkbox"/> Course 2	<input type="checkbox"/> Course 3
<input type="checkbox"/> Course 4	<input type="checkbox"/> Course 5	<input type="checkbox"/> Course 6

(If students click the button "Back", they will return to Web page "Using Existing Learning Activities".)

Show modules

Module

<input checked="" type="checkbox"/> Module 1	<input type="checkbox"/> Module 2	<input checked="" type="checkbox"/> Module 3
<input type="checkbox"/> Module 4	<input checked="" type="checkbox"/> Module 5	<input type="checkbox"/> Module 6

(Back to the Web page "Course")

Show other learning units, e.g. lectures, tests and/or group

Module 1

<input checked="" type="checkbox"/> Lecture 1	<input checked="" type="checkbox"/> Lecture 2	<input checked="" type="checkbox"/> Lecture 3
<input type="checkbox"/> Lecture 4	<input type="checkbox"/> Lecture 5	<input type="checkbox"/> Lecture 6

Module 3

<input type="checkbox"/> Lecture 1	<input checked="" type="checkbox"/> Lecture 2	<input type="checkbox"/> Lecture 3
<input checked="" type="checkbox"/> Test 1	<input checked="" type="checkbox"/> Lecture 4	<input checked="" type="checkbox"/> Test 2

Module 5

<input checked="" type="checkbox"/> Lecture 1	<input checked="" type="checkbox"/> Lecture 2	<input checked="" type="checkbox"/> Presentation 1
<input type="checkbox"/> Lecture 3	<input type="checkbox"/> Lecture 4	<input checked="" type="checkbox"/> Test 1

(When students select preferred courses, modules and other learning objects, they may view the content of objects in some presented Web pages, and get suggestions from staff through emails.)

(If students click the button "Submit", the system will be activated. If students click the button "Back", they will return to the Web page "Module".)

↓  
Create a Personalized Term for Lecture 1

Title	Identifier	Version Number	Address
Lecture 1	T001	T001.001	Http://

(According to the selected lectures, tests and presentations by students in figure 2, these parameters are captured and transferred by the system from vocabulary databases.)

Relation 1

Identifier

T001.001.T002.001 (The system can automatically search the selected learning objects in the same module.)

Resource

Title	Identifier	Version Number	Address	Type
Lecture 2	T002	T002.001	Http://	

The system will present a box to students to choose a relationship between lecture 1 and lecture 2, and the result will be recorded in the option "Type".

Relation 1  
Lecture 1  in front of Lecture 2

Relation 2

Identifier

T001.001.T003.001 (The system can automatically search the selected learning objects in the same module.)

Resource

Title	Identifier	Version Number	Address	Type
Lecture 3	T003	T003.001	Http://	

Relation 1  
Lecture 1  in front of Lecture 2

Relation 2  
Lecture 1  in front of Lecture 3

Then the system will present a "Lock" dialog to students.

Lock  Yes  No

This dialog indicates that whether students need to get the authorization from staff before they operate next learning units. If students select "Yes" in the option "Lock", they need to get the agreement from staff before they play next operations. If selecting "No", students may directly do the next performances without the opinions of staff. This dialog can provide more controlling rights for students to control their personal learning procedures.

↓  
Create a Personalized Term for Lecture 2

Title	Identifier	Version Number	Address
Lecture 2	T002	T002.001	Http://

Relation 1 (the same as described in the above diagram)  
Relation 2  
Identifier

T002.001.T003.001	(The system can automatically search the selected learning units in the same module.)
-------------------	---

Resource

Title	Identifier	Version Number	Address	Type
Lecture 3	T003	T003.001	Http://	

Relation 1  
Lecture 2  in front of Lecture 1

Relation 2  
Lecture 3  in front of Lecture 2

Then the system will present the "Lock" dialog box to students.

Lock  Yes  No

This dialog indicates that whether students need to get the authorization from staff before they operate next learning objects. If students select "Yes" in the option "Lock", they need to get the agreement from staff before they play next operations. If selecting "No", students may directly do the next performances without the opinions of staff. This dialog can provide more controlling rights for students to control their personal learning procedures.

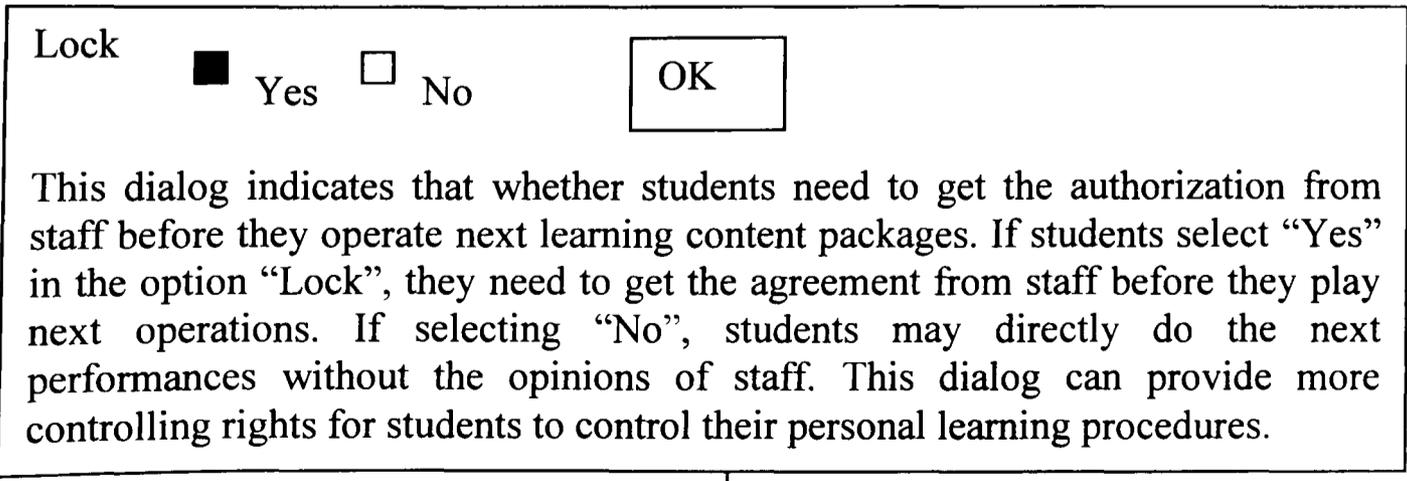
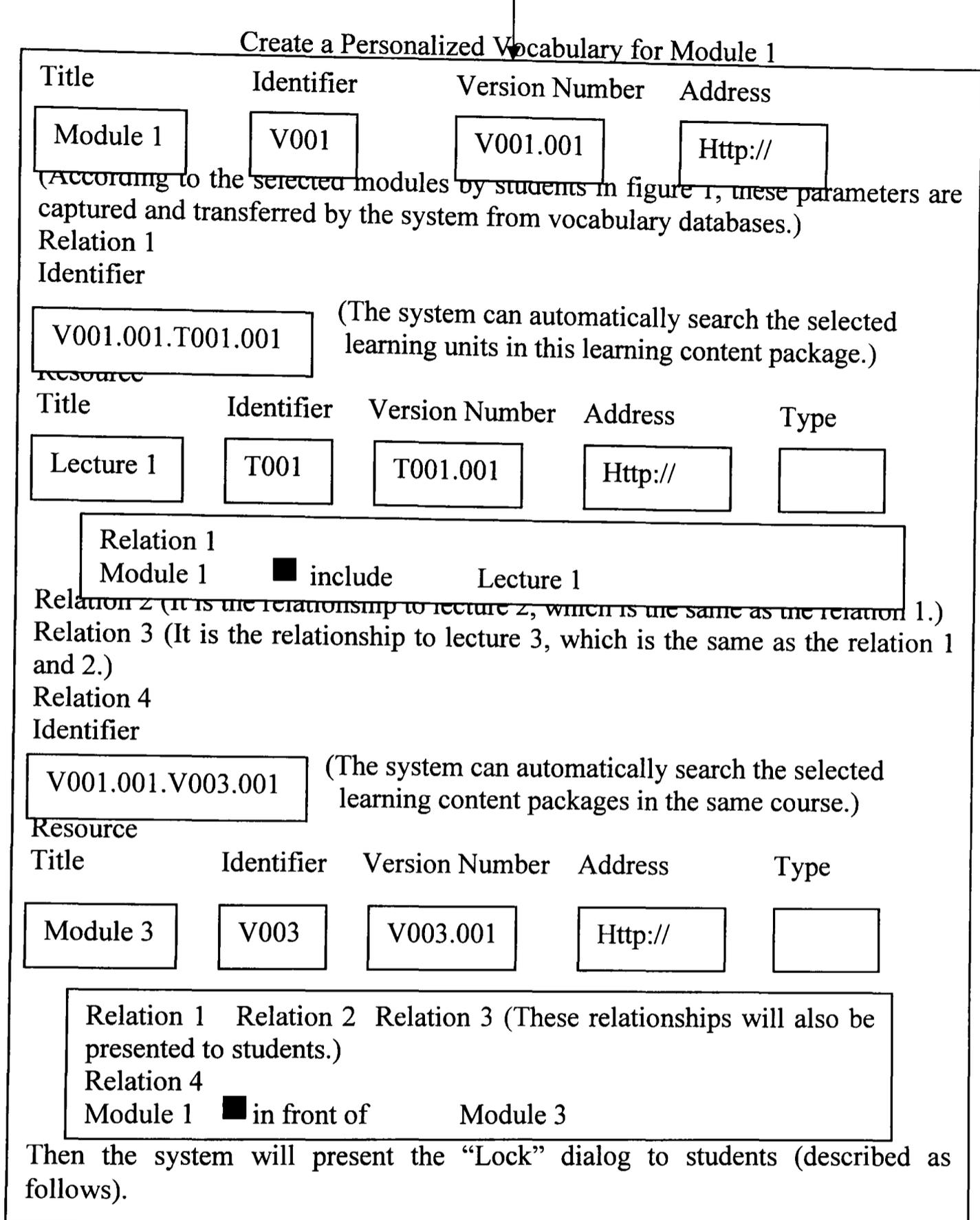
↓  
Create a Personalized Term for Lecture 3

The same as the above

↓  
Create Personalized Terms for other Selected Learning Units

The same as the above

9. Flowchart 6.2 the Flowchart of the Creation of Vocabularies for Individualized Collections of Learning Units



Create a Personalized Vocabulary for Module 3

Title	Identifier	Version Number	Address
Module 3	V003	V003.001	Http://

Relation 1

V003.001.T001.001 (The system can automatically search the selected learning objects in this learning content package.)

Resource

Title	Identifier	Version Number	Address	Type
Lecture 2	T010	T010.001	Http://	

Relation 1  
Module 3 ■ include Lecture 2

Relation 2, 3 and 4 (these relationships between module 3 and test 1, lecture 4 or test 2, the same as the description in relation 1)

Relation 5 (the relationship between module 3 and module 1, described as the above)

Relation 6

Identifier

V003.001.V005.001 (The system can automatically search the selected collections of learning units in the same course.)

Resource

Title	Identifier	Version Number	Address	Type
Module 5	V005	V005.001	Http://	

Relation 1, 2, 3, 4 and 5 (These relationships will also be presented to students.)  
Relation 6  
Module 3 ■ in front of Module 5

Then the system will present the "Lock" dialog to students (as above).

Create a Personalized Vocabulary for Module 5

The same as the creation of module 1 and 3

**10. Flowchart 6.3 the Flowchart of the Creation of Schemas for Individualized Learning Processes**

↓  
Create a Personalized Schema

Title	Identifier	Auto	Present	Version Number	Address
F	S008	Auto	Present	S008.001	Http://

(The "Title" dialog will be presented to students to input their specific names. The box of "Auto" and "Present" will also be presented to students. If students click the "Auto" box, the system will give an identifier automatically. If students choose "present", the system will present all titles related to the above title to students. Then, students choose one similar title, and the related identifier will be captured by the system. According to the identifier, the system can search the version numbers with the same identifier in vocabulary databases, and then plus one over the biggest number. When the schema is saved, the address can be given by students or indicated by the system.)

Relation 1  
Identifier

S008.001.V001.001

Resource

Title	Identifier	Version Number	Address	Type
Module 1	V001	V001.001	Http://	

Relation 1  
 F ■ include Module 1

Relation 2 and 3 (They are the relationships to module 3 and 5, which are the similar as the description in relation 1.)

Relation 4  
Identifier

S008.001.S002.001

Present

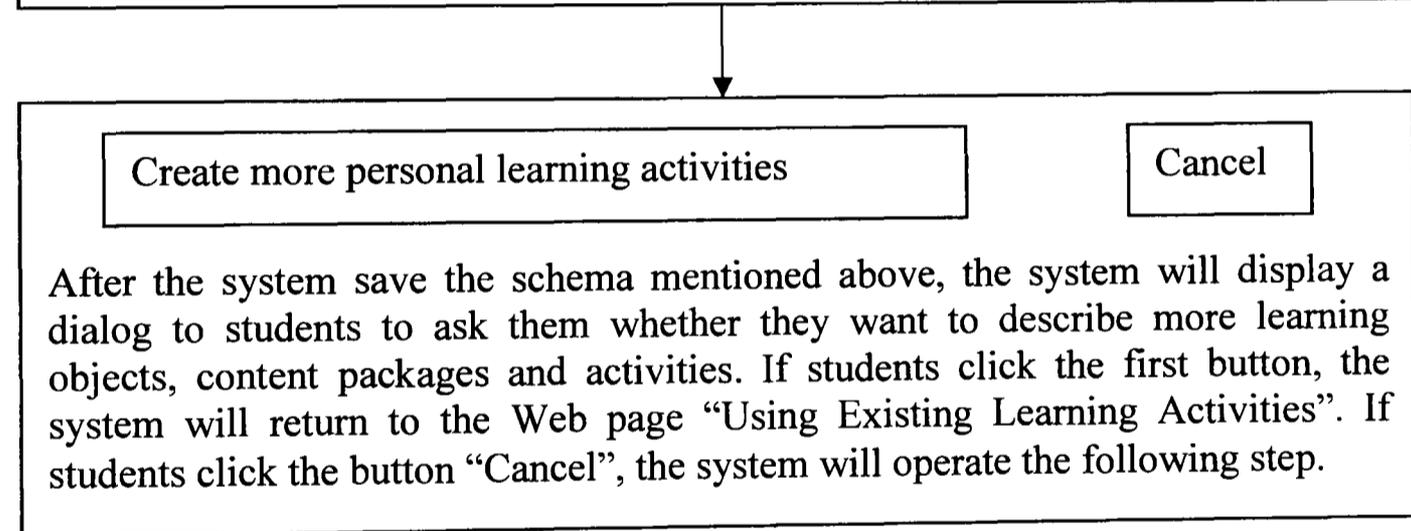
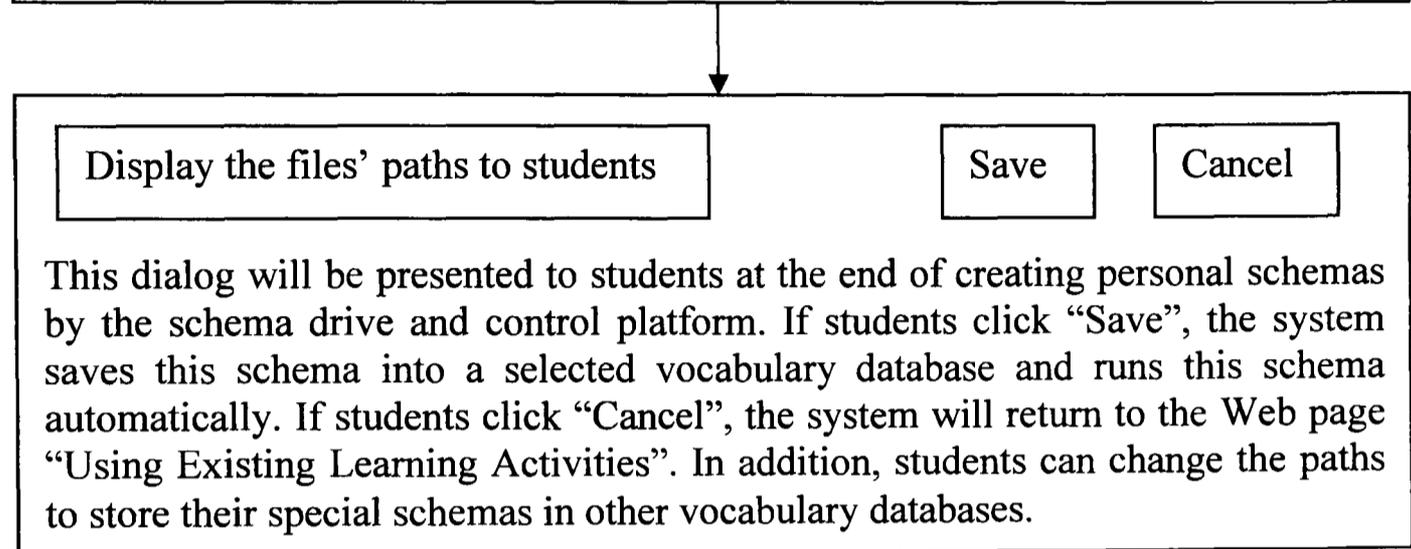
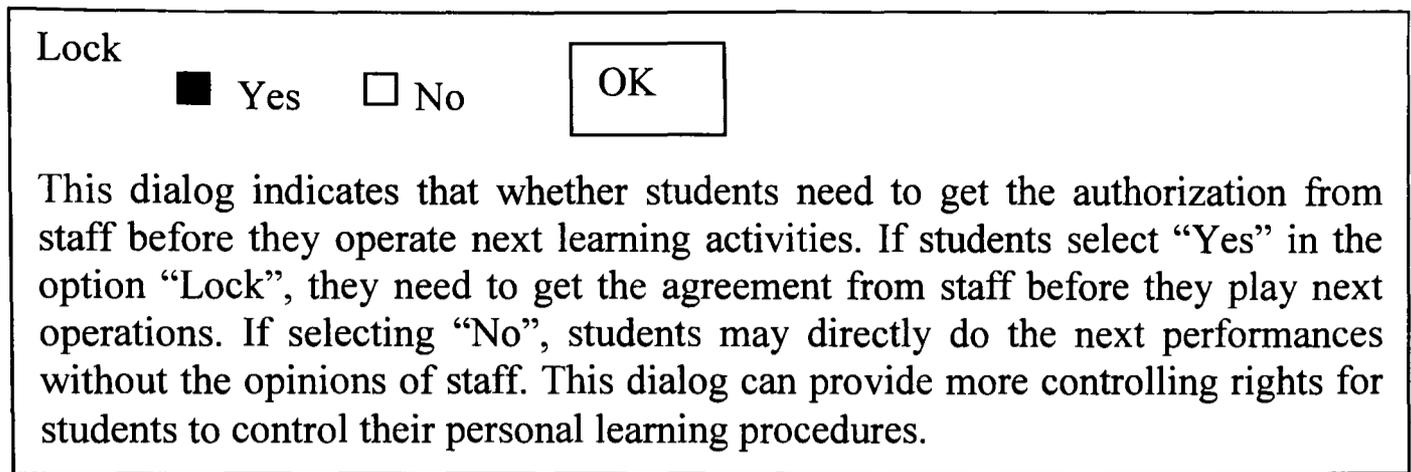
(The system will display the "Present" box to show students all titles of existing learning activities. Then students may choose some suitable learning activities to play. It is also for the modules in learning activity F.)

Resource

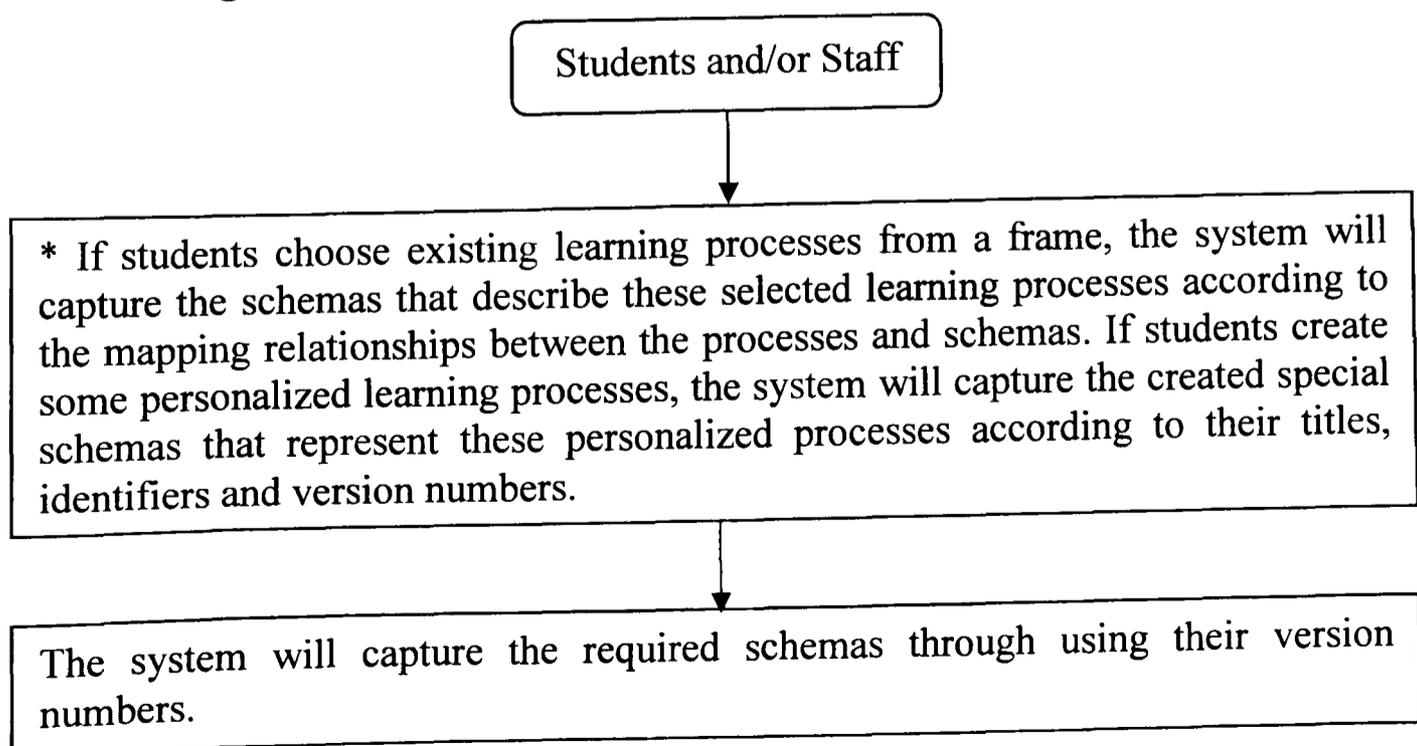
Title	Identifier	Version Number	Address	Type
B	S002	S002.001	Http://	

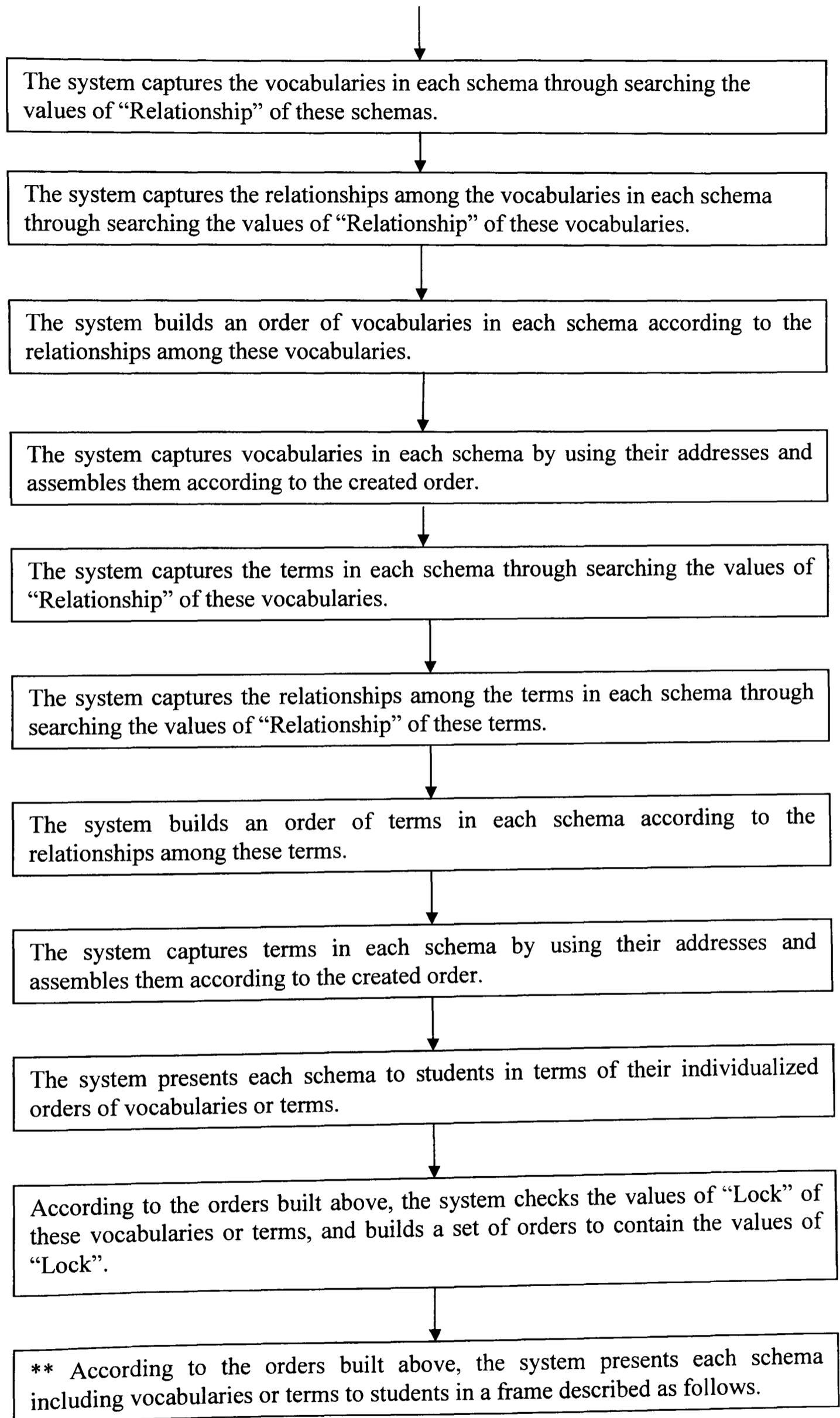
Relation 1   Relation 2   Relation 3 (These relationships will also be presented to students.)  
 Relation 4  
 F ■ in front of   B

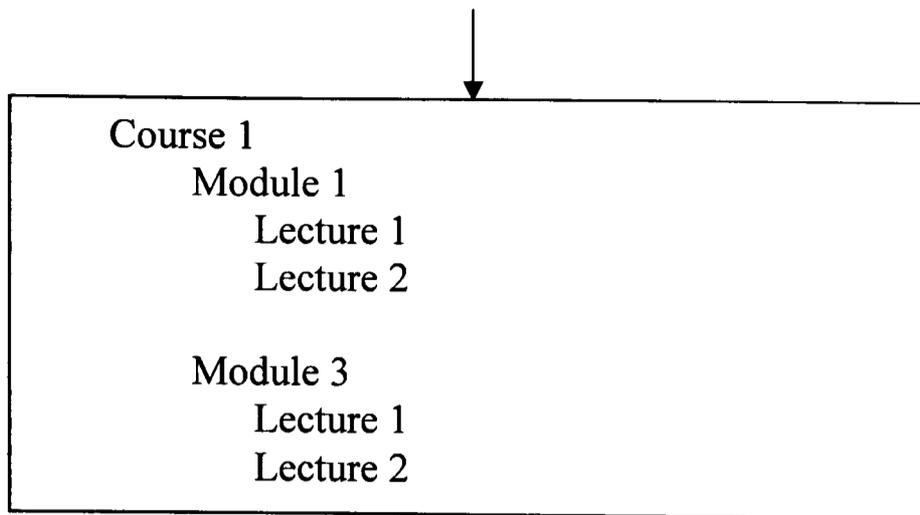
Then the system will present the "Lock" dialog to students (described as follows).



**11. Flowchart 6.4 the Flowchart of the Individualized Control of Teaching and Learning Processes**







Students start their learning processes in this frame. For example, lecture 1 will be opened, if it is not locked.

If students wish to open the locked learning units, the system sends a query to staff. The query consists of students' names, the titles and version numbers of learning units that students will perform, which can be described as follows.

Course	Student's name	Title	Identifier	Version Number
Course 1	<input type="text"/>	Lecture 1	T001	T001.001
<input type="button" value="Pass"/>	<input type="button" value="Fail"/>			

This is a Web page displayed to staff before the system activates the next learning activity or process. The system captures the titles, identifiers and version numbers of learning objects, learning content packages, and learning activities that students are performing, and presents them on this Web page. This page can provide the ability for staff to monitor any student's learning procedure. After staff assesses the assignments from students, they also need to click one of these two buttons to tell the system whether students can play the next learning activity or process. Before receiving the response from staff, the system will cause the running of this learning procedure.

Pass

Fail

If staff clicks the button "Pass", the system will perform operations from \*\*. That is, according to the orders mentioned above, the system will present the selected learning units to students.

If staff clicks the button "Fail", the system will present a dialog to students to decide whether they still want to continue their learning procedures.

↓

If students complete all required learning tasks, the system will return to the Webpage “Using Existing Learning Processes”.

↓

Repeat	Cancel
--------	--------

This is a dialog to students. If students click the button “Repeat”, the system will present the previous learning units to students to play it again. If students choose “Cancel”, they will return to the Web page “Using Existing Learning Processes”.

## *Appendix B---List of Detailed BNF Definitions*

### **1. The Composing Content of Schema**

Schema ::= Identifier Title VersionNumber Description Keywords  
SchemaListEntry {SchemaListEntry}  
VoabularyListEntry {VoabularyListEntry}  
| TermlistEntry {TermlistEntry}  
ContributeContact {ContributeEntity ContributeRole ContributeAddress}  
Relationship {SourceIdentifier SourceTitle SourceVersionNumber  
SourceLocation RelationType  
TargetIdentifier TargetTitle TargetVersionNumber  
TargetLocation};

### **2. The Composing Content of Vocabulary**

Vocabulary ::= Identifier Title VersionNumber Description Keywords  
VoabularyListEntry {VoabularyListEntry}  
TermlistEntry {TermlistEntry}  
ContributeContact {ContributeEntity ContributeRole  
ContributeAddress}  
Relationship {SourceIdentifier SourceTitle SourceVersionNumber  
SourceLocation RelationType  
TargetIdentifier TargetTitle TargetVersionNumber  
TargetLocation};

### **3. The Composing Content of Term**

Term ::= Identifier Title VersionNumber Description Keywords  
TermListEntry {TermListEntry}  
ContributeContact {ContributeEntity ContributeRole ContributeAddress}  
Relationship {SourceIdentifier SourceTitle SourceVersionNumber  
SourceLocation RelationType  
TargetIdentifier TargetTitle TargetVersionNumber  
TargetLocation};

## *Appendix C---Schemas, Ontologies, and Data Elements*

**1. Table 4.1 the Constructive Data Elements Used to Create Schemas**

Nr	Name	Meta Identifier	Explanation	Size	Order of Values	Value Space	Data Type	Mandatory or Optional
1	General	DES1	This category contains the general data elements describing the structure and semantic information of a schema.	1	N/A			Mandatory
1.1	Identifier	DES1.1	The identification of this schema, S001.	1	N/A			Mandatory
1.2	Title	DES1.2	The name of this schema.	1	N/A		LangString (SPM: 1000char)	Mandatory
1.3	Description	DES1.3	The description of the content of this schema.	SPM: 10 items	No		File	Mandatory
1.4	KeyWords	DES1.4	A few key words or phrases to describe this schema	SPM: 10 items	No		LangString (SPM:	Mandatory

							1000char)	
1.5	Schema lists	DES1.5	The lists of schemas in vocabulary databases.		No			Mandatory
1.5.1	Identifier	DES1.5.1	The identification numbers of these schema lists.		N/A	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
1.5.2	Entry	DES1.5.2	The titles of schemas within schema lists.	SPM: 100 items	No		LangString (SPM: 1000char)	Mandatory
1.6	Vocabulary lists	DES1.6	The lists of vocabularies in vocabulary databases.		No			Mandatory
1.6.1	Identifier	DES1.6.1	The identification numbers of these vocabulary lists.		N/A	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
1.6.2	Entry	DES1.6.2	The titles of vocabularies within vocabulary lists.	SPM: 100 items	No		LangString (SPM: 1000char)	Mandatory
1.7	Area	DES1.7	The area that this schema is used in.	SPM: 1000	No		LangString (SPM:	

				items			1000char)	
1.8	Cost	DES1.8	Whether use of this schema is free or not.	1	N/A		Dictionary	Mandatory
1.9	Age	DES1.9	The age limitation of use of this schema.	1	N/A	0-5 6-9 10-12 13-15 16-20 21-30 More than 31	Dictionary	Optional
1.10	Language	DES1.10	The national language used by this schema.	1	N/A	ISO 639-1:2002 and ISO 3166-1:1997	CharacterString (SPM: 30char)	Mandatory
1.11	Size	DES1.12	The size of this schema in bytes.	1	N/A	ISO 646, but only the digits '0'...'9'	CharacterString (SPM: 30char)	Mandatory
1.12	Reference List	DES1.12	The referenced materials when using this schema.	SPM: 30	Yes		LangString (SPM: 1000char)	Optional
1.12.	Catalog	DES1.12.	The identification number of the	1	N/A	Repertoire of	CharacterString	Mandatory

1		1	reference list of this schema.			ISO/IEC 10646-1	(SPM: 1000char)	
1.12. 2	Entry	DES1.12. 2	The values of these references.	SPM:30 items	Yes		LangString (SPM: 1000char)	Mandatory
1.13	Lock Unit	DES1.13	Whether can go to directly play the next schema.	1	No	Yes, No	CharacterString (SPM: 100char)	Mandatory
2	Contribute	DES2	The people and/or organizations that have affected the state of this schema during its evolution.	SPM: 30 items	No			Mandatory
2.1	Entity	DES2.1	The name of people and/or organizations contributing to this schema.	SPM: 40 items	Yes	Vcard	CharacterString (SPM: 1000char)	Mandatory
2.2	Contact	DES2.2	The contact information of the people and/or organizations.	SPM: 10 items	No		CharacterString (SPM: 1000char)	Mandatory
2.3	Role	DES2.3	Kind of contribution.	1	N/A	Author Publish Unknown User	Dictionary	Mandatory

						Initiator Terminator Editor Instructor Supervisor Learner System Manager Finance Manager Graphical Designer Technical Implementer Educational Validator Script Writer Instructional Designer		
2.4	Right	DES2.4	The available operations to this schema which can be done by the people	SPM: 10 items	No	Own Create	Dictionary	Mandatory

			and/or organizations.			Modify Delete Read Write Copy Validate		
2.5	Date	DES2.5	The date of the contribution.	1	N/A		Date	Mandatory
2.6	Version Number	DES2.6	The identification number of the version of this schema, such as S001.001.	1	N/A		CharacterString (SPM: 50char)	Mandatory
2.7	Location	DES2.7	The address to access this schema.	SPM: 10 items	No		LangString (SPM: 1000char)	Mandatory
2.8	State	DES2.8	The current status of this schema.	SPM: 3 items	No	Draft Final Revised Being Revised Available Unavailable	Ditionary	Mandatory

3	Annotation	DES3	This category provides data elements to describe comments on this schema.	SPM: 30 items	No			Mandatory
3.1	Entity	DES3.1	The people and/or organizations contributing to this annotation.	SPM: 40 items	Yes	Vcard	CharacterString (SPM: 1000char)	Mandatory
3.2	Role	DES3.2	The kind of this contribution.	1	N/A	Author Publish Unknown User Initiator Terminator System Manager Editor Graphical Designer Technical Implementer Educational Validator Script Writer	Dictionary	Mandatory

						Instructional Designer		
3.3	Date	DES3.3	The date of this contribution.	1	N/A		Date	Mandatory
3.4	Right	DES3.4	The available operations to this annotation which can be done by the people and/or organizations.	SPM: 10 items	No	Own Create Modify Delete Read Copy Validate	Dictionary	Mandatory
3.5	Version Number	DES3.5	The identification number of the version of this annotation, such as S001.001.A001.	1	N/A		CharacterString (SPM: 50char)	Mandatory
3.6	Contact	DES3.6	The contact information of the people and/or organizations contributing to this annotation.	SPM: 10 items	No		CharacterString (SPM: 1000char)	Mandatory
3.7	State	DES3.7	The current status of this annotation.	SPM: 3 items	No	Draft Final Revised	Ditionary	Mandatory

						Being Revised		
						Available		
						Unavailable		
3.8	Location	DES3.8	The Web addresses of the annotation.	SPM: 6 items	No		LangString (SPM: 1000char)	Optional
4	Relation	DES4	This category defines the data elements to describe the relationships between this schema and other schemas or its vocabularies.	SPM: 100 items	No			Mandatory
4.1	Identifier	DES4.1	The identification of this relationship.	1	N/A			Mandatory
4.2	Description	DES4.2	The representation of this relationship.	SPM: 10 items	No		File	Mandatory
4.3	Resource	DES4.3	The target schema or vocabulary that this relationship references.	1	N/A			Mandatory
4.3.1	Identifier	DES4.3.1	The unique identifier of the target schema or vocabulary.	1	N/A			Mandatory
4.3.2	Title	DES4.3.2	The name of the target schema or vocabulary.	1	N/A		LangString (SPM:	Mandatory

							1000char)	
4.3.3	Description	DES4.3.3	The information of the target schema or vocabulary.	1	No		LangString (SPM: 1000char)	Mandatory
4.3.4	Version Number	DES4.3.4	The version number of the target schema or vocabulary.	1	N/A		LangString (SPM: 1000char)	Mandatory
4.3.5	Location	DES4.3.5	A string to access the target schema or vocabulary.	SPM: 10 items	Yes	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
4.3.6	Type	DES4.3.6	The kind of this relationship.	1	N/A	Based on DCMI	Dictionary	Mandatory
4.4	Type Lists	DES4.4	Some lists of the collections of relationship kinds for schemas.	SPM:100 items	No			Mandatory
4.4.1	Identifier	DES4.4.1	The identification numbers of the relation type lists.	SPM: 10items	N/A			Mandatory
4.4.2	Entry	DES4.4.2	The values of types within each relation type list.	SPM: 100 items	N/A		LangString (SPM: 1000char)	Mandatory
4.4.3	Location	DES4.4.3	The Web addresses of these relation	SPM: 10	No		LangString	Mandatory

			type lists.	items			(SPM: 1000char)	
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## 2. Table 4.2 the Constructive Data Elements Used to Create Vocabularies

Nr	Name	Meta Identifier	Explanation	Size	Order of Values	Value Space	Data Type	Mandatory or Optional
1	General	DEV1	This category contains the general data elements describing the structure and semantic information of a vocabulary.	1	N/A			Mandatory
1.1	Identifier	DEV1.1	The identification of this vocabulary, V001.	1	N/A			Mandatory
1.2	Title	DEV1.2	The name of this vocabulary.	1	N/A		LangString (SPM: 1000char)	Mandatory
1.3	Description	DEV1.3	The description of the content of this vocabulary.	SPM: 10 items	No		File	Mandatory
1.4	KeyWords	DEV1.4	A few key words or phrases to describe this vocabulary	SPM: 10 items	No		LangString (SPM: 1000char)	Mandatory

1.5	Vocabulary lists	DEV1.5	The lists of vocabularies in vocabulary databases.		No			Mandatory
1.5.1	Identifier	DEV1.5.1	The identification numbers of these vocabulary lists.		N/A	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
1.5.2	Entry	DEV1.5.2	The titles of vocabularies within vocabulary lists.	SPM: 100 items	No		LangString (SPM: 1000char)	Mandatory
1.6	Term lists	DEV1.6	The lists of terms in vocabulary databases.	1	No			Mandatory
1.6.1	Identifier	DEV1.6.1	The identification numbers of these term lists.	1	No	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
1.6.2	Entry	DEV1.6.2	The titles of terms within term lists.	SPM: 1000 items	No		LangString (SPM: 1000char)	Mandatory
1.7	Area	DSV1.7	The area that this vocabulary is used in.	SPM: 1000 items	No		LangString (SPM: 1000char)	
1.7.1	Educational Type	DEV1.7.1	The educational or pedagogic type of this vocabulary.	SPM:10 items	Yes	Exercise Simulation	Dictionary	Operational

						Questionnaire Module Lecture Presentation Diagram Figure Graph Index Slide Table Narrative Text Exam Experiment Problem Statement Self Assessment		
1.7.2	Context	DEV1.7.2	The principal environment of use of this vocabulary.	SPM: 10 items	No	Primary Education Secondary Education Higher Education	Dictionary	Mandatory

						University First Cycle University Second Cycle University Postgraduate (Taught) University Postgraduate (Research) Technical School First Cycle Technical School Second Cycle Professional Formation Continuous Formation Vocational		
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						Formation		
1.7.3	Duration	DET1.7.3	The time to perform this vocabulary. This time is more advanced than the times for terms in this vocabulary.	SPM: 10 items	No		Datetime	Optional
1.8	Cost	DEV1.8	Whether use of this vocabulary is free or not.	1	N/A		Dictionary	Mandatory
1.9	Age	DEV1.9	The age limitation of use of this vocabulary.	1	N/A	0-5 6-9 10-12 13-15 16-20 21-30 More than 31	Dictionary	Optional
1.10	Language	DEV1.10	The national language used by this vocabulary.	1	N/A	ISO 639-1:2002 and ISO 3166-1:1997	CharacterString (SPM: 30char)	Mandatory
1.11	Size	DEV1.11	The size of this vocabulary in bytes.	1	N/A	ISO 646, but only the digits '0'...'9'	CharacterString (SPM: 30char)	Mandatory
1.12	Reference	DEV1.12	The referenced materials when using	SPM: 30	Yes		LangString	Optional

	List		this vocabulary.				(SPM: 1000char)	
1.12.1	Catalog	DEV1.12.1	The identification number of the reference list of this vocabulary.	1	N/A	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Optional
1.12.2	Entry	DEV1.12.2	The values of these references.	SPM:30 items	Yes		LangString (SPM: 1000char)	Optional
1.13	Format	DEV1.13	The format of this term	1	No		LangString (SPM: 1000char)	Optional
1.14	Lock Object Package	DEV1.14	Whether can go to directly play the next vocabulary.	1	No	Yes, No	CharacterString (SPM: 100char)	Mandatory
2	Contribute	DEV2	The people and/or organizations that have affected the state of this vocabulary during its evolution.	SPM: 30 items	No			Mandatory
2.1	Entity	DEV2.1	The name of people and/or organizations contributing to this vocabulary.	SPM: 40 items	Yes	Vcard	CharacterString (SPM: 1000char)	Mandatory
2.2	Contact	DEV2.2	The contact information of the people and/or organizations.	SPM: 10 items	No		CharacterString (SPM: 1000char)	Mandatory
2.3	Role	DEV2.3	Kind of contribution.	1	N/A	Author Publish	Dictionary	Mandatory

						Unknown User Initiator Terminator Editor Instructor Supervisor Learner System Manager Finance Manager Graphical Designer Technical Implementer Educational Validator Script Writer Instructional Designer		
2.4	Right	DEV2.4	The available operations to this	SPM: 10	No	Own	Dictionary	Mandatory

			vocabulary which can be done by the people and/or organizations.	items		Create Modify Delete Read Write Copy Validate		
2.5	Date	DEV2.5	The date of the contribution.	1	N/A		Date	Mandatory
2.6	Version Number	DEV2.6	The identification number of the version of this vocabulary, such as V001.001.	1	N/A		CharacterString (SPM: 50char)	Mandatory
2.7	Location	DEV2.7	The address to access this vocabulary.	SPM: 10 items	No		LangString (SPM: 1000char)	Mandatory
2.8	State	DEV2.8	The current status of this vocabulary.	SPM: 3 items	No	Draft Final Revised Being Revised Available Unavailable	Ditionary	Mandatory

3	Annotation	DEV3	This category provides data elements to describe comments on this vocabulary.	SPM: 30 items	No			Mandatory
3.1	Entity	DEV3.1	The people and/or organizations contributing to this annotation.	SPM: 40 items	Yes	Vcard	CharacterString (SPM: 1000char)	Mandatory
3.2	Role	DEV3.2	The kind of this contribution.	1	N/A	Author Publish Unknown User Initiator Terminator System Manager Editor Graphical Designer Technical Implementer Educational Validator Script Writer Instructional	Dictionary	Mandatory

						Designer		
3.3	Date	DEV3.3	The date of this contribution.	1	N/A		Date	Mandatory
3.4	Right	DEV3.4	The available operations to this annotation which can be done by the people and/or organizations.	SPM: 10 items	No	Own Create Modify Delete Read Copy Validate	Dictionary	Mandatory
3.5	Version Number	DEV3.5	The identification number of the version of this annotation, such as V001.001.A001.	1	N/A		CharacterString (SPM: 50char)	Mandatory
3.6	Contact	DEV3.6	The contact information of the people and/or organizations contributing to this annotation.	SPM: 10 items	No		CharacterString (SPM: 1000char)	Mandatory
3.7	State	DEV3.7	The current status of this annotation.	SPM: 3 items	No	Draft Final Revised Being Revised	Ditionary	Mandatory

						Available Unavailable		
3.8	Location	DEV3.8	The Web addresses of the annotation.	SPM: 6 items	No		LangString (SPM: 1000char)	Optional
4	Technical	DEV4	This category contains data elements that describe the technical requirements and characteristics of use of this vocabulary.	1	N/A			Mandatory
4.1	Name	DEV4.1	The name of required technology.	1	N/A		LangString (SPM: 1000char)	Mandatory
4.2	Type	DEV4.2	The kind of required technology.	1	N/A	Operating System Browser	Dictionary	Mandatory
4.3	Location	DEV4.3	A string to access this technology.	SPM: 10 items	N/A	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
4.4	Restriction	DEV4.4	The requirements to use this technology, such as minimum and/or maximum versions.	SPM: 10 items	No		LangString (SPM: 2000char)	Mandatory
4.5	Tutorial	DEV4.5	The direction of how to use this technology.	SPM: 10 items	No		File	Mandatory

5	Relation	DEV5	This category defines data elements that describe the relationships between this vocabulary and other vocabularies or its terms.	SPM: 100 items	No			Mandatory
5.1	Identifier	DEV5.1	The identification of this relationship.	1	N/A			Mandatory
5.2	Description	DEV5.2	The representation of this relationship.	SPM: 10 items	No		File	Mandatory
5.3	Resource	DEV5.3	The target vocabulary or term that this relationship references.	1	N/A			Mandatory
5.3.1	Identifier	DEV5.3.1	The unique identifier of the target term or vocabulary.	1	N/A			Mandatory
5.3.2	Title	DEV5.3.2	The name of the target term or vocabulary.	1	N/A		LangString (SPM: 1000char)	Mandatory
5.3.3	Description	DEV5.3.3	The information of the target term or vocabulary.	1	No		LangString (SPM: 1000char)	Mandatory
5.3.4	Version Number	DEV5.3.4	The version number of the target term or vocabulary.	1	N/A		LangString (SPM: 1000char)	Mandatory
5.3.5	Location	DEV5.3.5	A string to access the target term or	SPM: 10	Yes	Repertoire of	CharacterString	Mandatory

			vocabulary.	items		ISO/IEC 10646-1	(SPM: 1000char)	
5.3.6	Type	DEV5.3.6	The kind of this relationship.	1	N/A	Based on DCMI	Dictionary	Mandatory
5.4	Type Lists	DEV5.4	Some lists of the collections of relationship kinds for vocabularies.	SPM:10 items	No			Mandatory
5.4.1	Identifier	DEV5.4.1	The identification numbers of the relation type lists.	SPM:10 items	N/A			Mandatory
5.4.2	Entry	DEV5.4.2	The values of types within each relation type list.	SPM: 100 items	N/A		LangString (SPM: 1000char)	Mandatory
5.4.3	Location	DEV5.4.3	The Web addresses of these relation type lists.	SPM: 10 items	No		LangString (SPM: 1000char)	Mandatory

### 3. Table 4.3 the Constructive Data Elements Used to Create Terms

Nr	Name	Meta Identifier	Explanation	Size	Order of Values	Value Space	Data Type	Mandatory or Optional
1	General	DET1	This category contains the general data elements describing the	1	N/A			Mandatory

			structure and semantic information of a term.					
1.1	Identifier	DET1.1	The identification of this term, T001.	1	N/A			Mandatory
1.2	Title	DET1.2	The name of this term.	1	N/A		LangString (SPM: 1000char)	Mandatory
1.3	Description	DET1.3	The description of the content of this term.	SPM: 10 items	No		File	Mandatory
1.4	KeyWords	DET1.4	A few key words or phrases to describe this term.	SPM: 10 items	No		LangString (SPM: 1000char)	Mandatory
1.5	Term lists	DET1.5	The lists of terms in vocabulary databases.	1	No			Mandatory
1.5.1	Identifier	DET1.5.1	The identification numbers of these term lists.	1	No	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
1.5.2	Entry	DET1.5.2	The titles of terms within term lists.	SPM: 1000 items	No		LangString (SPM: 1000char)	Mandatory
1.6	Area	DST1.6	The area that this term is used in.	SPM: 1000 items	No		LangString (SPM: 1000char)	

1.6.1	Education al Type	DET1.6.1	The educational or pedagogic type of this term.	SPM:10 items	Yes	Exercise Simulation Questionnaire Module Lecture Presentation Diagram Figure Graph Index Slide Table Narrative Text Exam Experiment Problem Statement Self Assessment	Dictionary	Operational
1.6.2	Context	DET1.6.2	The principal environment of use of this term.	SPM: 10 items	No	Primary Education Secondary	Dictionary	Mandatory

						Education Higher Education University First Cycle University Second Cycle University Postgraduate (Taught) University Postgraduate (Research) Technical School First Cycle Technical School Second Cycle Professional Formation Continuous		
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						Formation Vocational Formation		
1.6.3	Duration	DET1.6.3	The time to perform this term.	SPM: 10 items	No		Datetime	Optional
1.7	Cost	DET1.7	Whether use of this term is free or not.	1	N/A		Dictionary	Mandatory
1.8	Age	DET1.8	The age limitation of use of this term.	1	N/A	0-5 6-9 10-12 13-15 16-20 21-30 More than 31	Dictionary	Optional
1.9	Language	DET1.9	The national language used by this term.	1	N/A	ISO 639-1:2002 and ISO 3166-1:1997	CharacterString (SPM: 30char)	Mandatory
1.10	Size	DET1.10	The size of this term in bytes.	1	N/A	ISO 646, but only the digits '0'...'9'	CharacterString (SPM: 30char)	Mandatory

1.11	Reference List	DET1.11	The referenced materials when using this term.	SPM: 30 items	Yes		LangString (SPM: 1000char)	Optional
1.11.1	Catalog	DET1.11.1	The identification number of the reference list of this term.	1	N/A	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Optional
1.11.2	Entry	DET1.11.2	The values of these references.	SPM:30 items	Yes		LangString (SPM: 1000char)	Optional
1.12	Format	DET1.12	The format of this term	1	No		LangString (SPM: 1000char)	Optional
1.13	Lock Object	DET1.13	Whether can go to directly play the next term.	1	No	Yes, No	CharacterString (SPM: 100char)	Mandatory
2	Contribute	DET2	The people and/or organizations that have affected the state of this term during its evolution.	SPM: 30 items	No			Mandatory
2.1	Entity	DET2.1	The name of people and/or organizations contributing to this term.	SPM: 40 items	Yes	Vcard	CharacterString (SPM: 1000char)	Mandatory
2.2	Contact	DET2.2	The contact information of the people and/or organizations.	SPM: 10 items	No		CharacterString (SPM: 1000char)	Mandatory
2.3	Role	DET2.3	Kind of contribution.	1	N/A	Author Publish	Dictionary	Mandatory

						Unknown User Initiator Terminator Editor Instructor Supervisor Learner System Manager Finance Manager Graphical Designer Technical Implementer Educational Validator Script Writer Instructional Designer		
2.4	Right	DET2.4	The available operations to this term	SPM: 10	No	Own	Dictionary	Mandatory

			which can be done by the people and/or organizations.	items		Create Modify Delete Read Write Copy Validate		
2.5	Date	DET2.5	The date of the contribution.	1	N/A		Date	Mandatory
2.6	Version Number	DET2.6	The identification number of the version of this term, such as T001.001.	1	N/A		CharacterString (SPM: 50char)	Mandatory
2.7	Location	DET2.7	The address to access this term.	SPM: 10 items	No		LangString (SPM: 1000char)	Mandatory
2.8	State	DET2.8	The current status of this term.	SPM: 3 items	No	Draft Final Revised Being Revised Available Unavailable	Ditionary	Mandatory

3	Annotation	DET3	This category provides data elements to describe comments on this term.	SPM: 30 items	No			Mandatory
3.1	Entity	DET3.1	The people and/or organizations contributing to this annotation.	SPM: 40 items	Yes	Vcard	CharacterString (SPM: 1000char)	Mandatory
3.2	Role	DET3.2	The kind of this contribution.	1	N/A	Author Publish Unknown User Initiator Terminator System Manager Editor Graphical Designer Technical Implementer Educational Validator Script Writer Instructional Designer	Dictionary	Mandatory

3.3	Date	DET3.3	The date of this contribution.	1	N/A		Date	Mandatory
3.4	Right	DET3.4	The available operations to this annotation which can be done by the people and/or organizations.	SPM: 10 items	No	Own Create Modify Delete Read Copy Validate	Dictionary	Mandatory
3.5	Version Number	DET3.5	The identification number of the version of this annotation, such as T001.001.A001.	1	N/A		CharacterString (SPM: 50char)	Mandatory
3.6	Contact	DET3.6	The contact information of the people and/or organizations contributing to this annotation.	SPM: 10 items	No		CharacterString (SPM: 1000char)	Mandatory
3.7	State	DET3.7	The current status of this annotation.	SPM: 3 items	No	Draft Final Revised Being Revised Available	Ditionary	Mandatory

						Unavailable		
3.8	Location	DET3.8	The Web addresses of the annotation.	SPM: 6 items	No		LangString (SPM: 1000char)	Optional
4	Technical	DET4	This category contains data elements that describe the technical requirements and characteristics of use of this term.	1	N/A			Mandatory
4.1	Name	DET4.1	The name of required technology.	1	N/A		LangString (SPM: 1000char)	Mandatory
4.2	Type	DET4.2	The kind of required technology.	1	N/A	Operating System Browser	Dictionary	Mandatory
4.3	Location	DET4.3	A string to access this technology.	SPM: 10 items	N/A	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
4.4	Restriction	DET4.4	The requirements to use this technology, such as minimum and/or maximum versions.	SPM: 10 items	No		LangString (SPM: 2000char)	Mandatory
4.5	Tutorial	DET4.5	The direction of how to use this technology.	SPM: 10 items	No		File	Mandatory
5	Relation	DET5	This category defines the	SPM:	No			Mandatory

			relationships between this term and other terms.	100 items				
5.1	Identifier	DET5.1	The identification of this relationship.	1	N/A			Mandatory
5.2	Description	DET5.2	The representation of this relationship.	SPM: 10 items	No		File	Mandatory
5.3	Resource	DET5.3	The target term that this relationship references.	1	N/A			Mandatory
5.3.1	Identifier	DET5.3.1	The unique identifier of the target term.	1	N/A			Mandatory
5.3.2	Title	DET5.3.2	The name of the target term.	1	N/A		LangString (SPM: 1000char)	Mandatory
5.3.3	Description	DET5.3.3	The information of the target term.	1	No		LangString (SPM: 1000char)	Mandatory
5.3.4	Version Number	DET5.3.4	The version number of the target term.	1	N/A		LangString (SPM: 1000char)	Mandatory
5.3.5	Location	DET5.3.5	A string to access the target term.	SPM: 10 items	Yes	Repertoire of ISO/IEC 10646-1	CharacterString (SPM: 1000char)	Mandatory
5.3.6	Type	DET5.3.6	The kind of this relationship.	1	N/A	Based on DCMI	Dictionary	Mandatory

5.4	Type Lists	DET5.4	Some lists of the collections of relationship kinds for terms.	SPM:10 items	No			Mandatory
5.4.1	Identifier	DET5.4.1	The identification numbers of the relation type lists.	SPM:10 items	N/A			Mandatory
5.4.2	Entry	DET5.4.2	The values of types within each relation type list.	SPM: 100 items	N/A		LangString (SPM: 1000char)	Mandatory
5.4.3	Location	DET5.4.3	The Web addresses of these relation type lists.	SPM: 10 items	No		LangString (SPM: 1000char)	Mandatory

#### 4. Table 5.1 A Sample of Terms

Nr	Name	Content
1	General	
1.1	Identifier	T001
1.2	Title	Lecture 1
1.3	Description	Introduce the basic commands of Java Programming language.
1.4	KeyWords	Basic commands
1.5	Term lists	

1.5.1	Identifier	TL001			
1.5.2	Entry	Basic commands of Java Programming language, An example of Java, Java technology Architecture Details, Examination of Java Programming Language			
1.6	Area	Higher Education			
1.6.1	Educational Type	Module			
1.6.2	Context				
1.6.3	Duration	4 hours			
1.7	Cost	£			
1.8	Age				
1.9	Language	English			
1.10	Size				
1.11	Reference List				
1.11.1	Catalog				
1.11.2	Entry				
1.12	Format	Word Document			
1.13	Lock Object	Yes			
2	Contribute				
2.1	Entity	Entity A	Entity B	Entity C	Entity D

2.2	Contact	EntityA@Yahoo.co.uk	EntityB@Yahoo.co.uk	EntityC@Yahoo.co.uk	EntityD@Yahoo.co.uk
2.3	Role	Author	System Manager	Finance Manager	Modifier
2.4	Right	Own, Create, Modify, Delete, Read, Copy	Validate	Validate	Own, Create, Modify, Delete, Read, Copy
2.5	Date	26/02/04	29/03/04	29/03/04	18/03/04
2.6	Version Number	T001.001	T001.001, T001.002	T001.001, T001.002	T001.002
2.7	Location	Http://			
2.8	State	Final, Available	Final, Available	Final, Available	Final, Available
3	Annotation				
3.1	Entity	Entity E	Entity B	Entity C	Entity H
3.2	Role	Author	System Manager	Finance Manager	Modifier
3.3	Date	01/09/04	20/09/04	20/09/04	10/09/04
3.4	Right	Own, Create, Modify, Delete, Read, Copy	Validate	Validate	Own, Create, Modify, Delete, Read, Copy
3.5	Version	T001.001.A001	T001.001.A001,	T001.001.A001,	T001.001.A002

	Number		T001.001.A002	T001.001.A002	
3.6	Contact	EntityE@Yahoo.co.uk	EntityB@Yahoo.co.uk	EntityC@Yahoo.co.uk	EntityH@Yahoo.co.uk
3.7	State	Final, Available	Final, Available	Final, Available	Draft, Unavailable
3.8	Location	Http://	Http://, Http://	Http://, Http://	Http://
4	Technical				
4.1	Name	Microsoft Word			
4.2	Type	Software			
4.3	Location	Http://			
4.4	Restriction	Word 97 or up			
4.5	Tutorial				
5	Relation				
5.1	Identifier	T001.001.T002.001		T001.001.T003.001	
5.2	Description	Before users can perform T002.001, users need to complete T001.001		If users want to know more knowledge about basic Java commands, T003.001 is performed.	
5.3	Resource				
5.3.1	Identifier	T002		T003	
5.3.2	Title	Lecture 2		External Lecture 1	

5.3.3	Description	Explain some Java examples.	Introduce more details about the basic Java commands.
5.3.4	Version Number	T002.001	T003.001
5.3.5	Location	Http://	Http://
5.3.6	Type	In front of	In front of
5.4	Type Lists		
5.4.1	Identifier	TRTL001	
5.4.2	Entry	In front of, Behind	
5.4.3	Location	Http://	

**5. Table 5.2 A Sample of Vocabularies**

Nr	Name	Content
1	General	
1.1	Identifier	V001
1.2	Title	Module 1: Java Programming language
1.3	Description	This module aims to allow learners to have the basic programming ability in Java. It is assessed on the basis of attendance, tests' results and a presentation.
1.4	KeyWords	Java, Programming Language

1.5	Vocabulary lists	
1.5.1	Identifier	VL001
1.5.2	Entry	Java Programming Language, A Project Based on Java Technology
1.6	Term lists	
1.6.1	Identifier	TL001
1.6.2	Entry	Basic commands of Java Programming language, An example of Java, Java technology Architecture Details, Examination of Java Programming Language
1.7	Area	Higher Education
1.7.1	Educational Type	Module
1.7.2	Context	
1.7.3	Duration	3 months
1.8	Cost	£
1.9	Age	
1.10	Language	English
1.11	Size	
1.12	Reference List	
1.12.1	Catalog	
1.12.2	Entry	

1.13	Format	HTML Web Pages			
1.14	Lock Object Package	Yes			
2	Contribute				
2.1	Entity	Entity A	Entity B	Entity C	Entity D
2.2	Contact	EntityA@Yahoo.co.uk	EntityB@Yahoo.co.uk	EntityC@Yahoo.co.uk	EntityD@Yahoo.co.uk
2.3	Role	Author	System Manager	Finance Manager	Modifier
2.4	Right	Own, Create, Modify, Delete, Read, Copy	Validate	Validate	Own, Create, Modify, Delete, Read, Copy
2.5	Date	26/04/04	29/05/04	29/05/04	10/05/04
2.6	Version Number	V001.001	V001.001, V001.002	V001.001, V001.002	V001.002
2.7	Location	Http://			
2.8	State	Final, Available	Final, Available	Final, Available	Final, Available
3	Annotation				
3.1	Entity	Entity E	Entity B	Entity C	Entity H
3.2	Role	Author	System Manager	Finance Manager	Modifier

3.3	Date	01/10/04	20/10/04	20/10/04	10/10/04
3.4	Right	Own, Create, Modify, Delete, Read, Copy	Validate	Validate	Own, Create, Modify, Delete, Read, Copy
3.5	Version Number	V001.001.A001	V001.001.A001, V001.001.A002	V001.001.A001, V001.001.A002	T001.001.A002
3.6	Contact	EntityE@Yahoo.co.uk	EntityB@Yahoo.co.uk	EntityC@Yahoo.co.uk	EntityH@Yahoo.co.uk
3.7	State	Final, Available	Final, Available	Final, Available	Draft, Unavailable
3.8	Location	Http://	Http://, Http://	Http://, Http://	Http://
4	Technical				
4.1	Name	Internet Explorer, Microsoft Word			
4.2	Type	Software			
4.3	Location	Http://			
4.4	Restriction	IE 5.0 or up or Netscape 6.0, Word 97 or up			
4.5	Tutorial				
5	Relation				
5.1	Identifier	V001.001.T001.001	V001.001.T002.001	V001.001.V002.001	

5.2	Description	The vocabulary V001.001 contains the term T001.001	The vocabulary V001.001 contains the term T002.001	The vocabulary V001.001 is followed by the vocabulary V002.001
5.3	Resource			
5.3.1	Identifier	T001	T002	V002
5.3.2	Title	Lecture 1	Lecture 2	Module 2
5.3.3	Description	Introduce the basic commands of Java Programming language.	Explain some Java examples.	An project to use Java to complete a finance management program.
5.3.4	Version Number	T001.001	T002.001	V002.001
5.3.5	Location	Http://	Http://	Http://
5.3.6	Type	Contain	contain	In front of
5.4	Type Lists			
5.4.1	Identifier	VRTL001		
5.4.2	Entry	In front of, Behind, Contain, Not Contain		
5.4.3	Location	Http://		

**6. Table 5.3 A Sample of Schemas**

Nr	Name	Content
1	General	
1.1	Identifier	S001
1.2	Title	Learning Java Programming language (basis)
1.3	Description	Teaching users how to use Java to program.
1.4	KeyWords	Java, program
1.5	Schema lists	
1.5.1	Identifier	SL001
1.5.2	Entry	Learning Java Programming language (basis), Professional Java Programming, Learning C Programming Language
1.6	Vocabulary lists	
1.6.1	Identifier	VL001
1.6.2	Entry	Java Programming Language, A Project Based on Java Technology
1.7	Area	Higher Education
1.8	Cost	£
1.9	Age	
1.10	Language	English
1.11	Size	

1.12	Reference List				
1.12.1	Catalog				
1.12.2	Entry				
1.13	Lock Unit	Yes			
2	Contribute				
2.1	Entity	Entity A	Entity B	Entity C	Entity D
2.2	Contact	EntityA@Yahoo.co.uk	EntityB@Yahoo.co.uk	EntityC@Yahoo.co.uk	EntityD@Yahoo.co.uk
2.3	Role	Author	System Manager	Finance Manager	Modifier
2.4	Right	Own, Create, Modify, Delete, Read, Copy	Validate	Validate	Own, Create, Modify, Delete, Read, Copy
2.5	Date	08/06/04	29/06/04	29/06/04	16/06/04
2.6	Version Number	S001.001	S001.001, S001.002	S001.001, S001.002	S001.002
2.7	Location	Http://			
2.8	State	Final, Available	Final, Available	Final, Available	Final, Available
3	Annotation				
3.1	Entity	Entity E	Entity B	Entity C	Entity H
3.2	Role	Author	System Manager	Finance Manager	Modifier

3.3	Date	01/11/04	20/11/04	20/11/04	10/11/04
3.4	Right	Own, Create, Modify, Delete, Read, Copy	Validate	Validate	Own, Create, Modify, Delete, Read, Copy
3.5	Version Number	S001.001.A001	S001.001.A001, S001.001.A002	S001.001.A001, S001.001.A002	S001.001.A002
3.6	Contact	EntityE@Yahoo.co.uk	EntityB@Yahoo.co.uk	EntityC@Yahoo.co.uk	EntityH@Yahoo.co.uk
3.7	State	Final, Available	Final, Available	Final, Available	Draft, Unavailable
3.8	Location	Http://	Http://, Http://	Http://, Http://	Http://
4	Relation				
4.1	Identifier	S001.001.V001.001	S001.001.V002.001	S001.001.S002.001	
4.2	Description	The schema S001.001 contains the vocabulary V001.001	The schema S001.001 contains the vocabulary V002.001	Passing the schema S001.001 is the precondition to perform the schema S002.001	
4.3	Resource				
4.3.1	Identifier	V001	V002	S002	
4.3.2	Title	Module 1	Module 2	Professional Java Programming	
4.3.3	Description	This module aims to allow learners to have the basic programming	An project to use Java to complete a finance management program.	This aims to allow learners to become an expert in Java	

		ability in Java.		programming.
4.3.4	Version Number	V001.001	V002.001	S002.001
4.3.5	Location	Http://	Http://	Http://
4.3.6	Type	Contain	contain	In front of
4.4	Type Lists			
4.4.1	Identifier	SRTL001		
4.4.2	Entry	In front of, Behind, Contain, Not Contain		
4.4.3	Location	Http://		

#### 7. Table 5.4 Table of Schemas in a Database

Schema Identifier	List	Schema Location	List	Schema Identifier	Schema Version Number	Schema List Entry
SL001		Http://		S001	S001.001	Learning Java Programming language (basis)
SL001		Http://		S001	S001.002	Learning Java Programming language (basis)
SL001		Http://		S002	S002.001	Professional Java Programming
SL001		Http://		S003	S003.001	Learning C Programming Language
SL002		Http://		S001	S001.001	Game Programming (First Year)
SL002		Http://		S002	S002.001	Game Programming (Second Year)
SL002		Http://		S003	S003.001	Game Programming (Third Year)
SL003		Http://		S001	S001.001	The Management of Software Development

**8. Table 5.5 Table of Vocabularies in a Database**

Vocabulary List Identifier	Vocabulary List Location	Vocabulary Identifier	Vocabulary Version Number	Vocabulary List Entry
VL001	Http://	V001	V001.001	Java Programming Language
VL001	Http://	V001	V001.002	Java Programming Language
VL001	Http://	V002	V002.001	A Project Based on Java Technology
VL001	Http://	V003	V003.001	Results Assessment
VL002	Http://	V001	V001.001	Network Architecture
VL002	Http://	V002	V002.001	The examples of C Programming Language
VL002	Http://	V003	V003.001	Results Assessment
VL003	Http://	V001	V001.001	Software Engineering

**9. Table 5.6 Table of Terms in a Database**

Term List Identifier	Term List Location	Term Identifier	Term Version Number	Term List Entry
TL001	Http://	T001	T001.001	Basic commands of Java Programming language
TL001	Http://	T001	T001.002	Basic commands of Java Programming language
TL001	Http://	T002	T002.001	An example of Java
TL001	Http://	T003	T003.001	Java technology Architecture Details
TL001	Http://	T004	T004.001	Examination of Java Programming Language
TL002	Http://	T001	T001.001	An example of C
TL002	Http://	T002	T002.001	Basic commands of C Programming language
TL002	Http://	T003	T003.001	Some Exercises of C

## *Appendix D---Evaluation Methodology*

### **1. Introduction**

Evaluation refers to assessing the features and limitations of our designs, prototypes, and fully completed systems [337]. It aims to show whether a design process, program, or product actually performs the behaviours as we expect and matches with users' requirements. Evaluation is always performed throughout the design life cycle, which can ensure that the problems of every stage of development can be found as soon as possible. Also it is much easier to modify a design in the early stages than the later ones [338]. That is, the later that a problem is discovered in a development process, the more cost that will be spent to correct this error. So evaluation is very helpful for researchers to complete their design activities effectively.

The main goals of evaluation can be described as follows:

- Evaluation aims to check whether the functionality of a system meets users' demands or not [339]. In detail, the required functions should be provided to users by a system, which refers to the extent of the functionality of the system. Also users' performance on a system needs to be recorded (e.g. which behaviours can be supported and which can not) to analyze the advantages and limitations of the tool.
- Evaluation aims to assess users' experience of the interaction with a system [340]. This includes whether a system is easy to be used, how well the usability of a system is, and whether a user is satisfied with a system. Furthermore, the aspects of a system which overload users should be found, such as users are asked to remember too much information in order to run a system.
- Evaluation aims to find and deal with the special problems of a system which involve the areas of both functionality and usability [341]. For example, a system is used in different contexts set by different users. This may cause unexpected problems, such as the system runs well in an environment (e.g. Windows XP) but does not work in another (e.g. Unix).

### **2. Approaches of Assessment**

Generally, evaluation methods are divided into two categories in terms of whether they are performed in user testing. One class is evaluation through expert analysis in which a set of human factors experts identify and analyze any aspect of a design,

prototype, or product which may cause difficulties to users [342]. Another is evaluation by user participation in which the potential users of a system are invited to do actual usability testing with this tool [343].

Both expert-based analysis and user testing can be used at any stage in the development process including a design specification, prototypes, and fully completed software. Furthermore, they can be adopted in the assessment of functionality, usability, and specific problems of a system (section 1.). One of the main differences between these evaluation approaches is that expert analysis does not assess actual use of a system, but asks experts to check the potential usability problems for people who may use this system [344]. So expert analysis relies heavily on the knowledge, experiences, and expertises of evaluators. Another different thing is that it is usually more expensive to do user testing during a design process or on a full implementation, because this assessment method requires user involvement. Furthermore, sometimes it is difficult to perform extensive experimental testing on a design process, prototype, or product. For example, a design process is incompleted, the interfaces that a prototype provides to users are not friendly, or the researcher can not find enough users to do the practical testing of a full implementation.

In each category of the evaluation through expert-based analysis or user participation, there are a set of different approaches to assess a design process or system. As it is not necessary to present all the methods in this thesis, so we discussed three evaluation techniques in expert analysis: Cognitive walkthrough [345], heuristic evaluation [336], and model-based assessment [346] [347]. Next, we described three evaluation approaches in actual user test: experiment [348], interviews [349], and questionnaire [350]. Through investigating these methods, a suitable one was selected to complete the case study in this thesis.

The representation of the three expert analysis methods is shown in the following:

- Cognitive walkthrough developed by Polson and colleagues [351] [352] focuses on evaluating how easy a system is to learn through simulating users in doing their goal-driven exploration activities under the navigation system of a website.
- Heuristic evaluation from Nielsen refers to structuring the critique of a design specification, prototypes, and tools with full functions by using a set of relative heuristics. A heuristic is a general principle used to describe an area of the

usability of a system on the high level, such as the ability of learner control in an e-learning tool.

- Model-based evaluation [353] is a method in which cognitive and design models predict users' operations with a design specification, methodologies, or building blocks of a system (e.g. a user interface). For instance, the GOMS (goals, operators, methods, and selection) [346] [347] model can produce useful predictions about users' behaviours in completing their selected tasks. Moreover, by inspecting the criteria associated with every item included in a designing framework of a system, the relevant evidence is obtained to assess this design process. In addition, dialog models can be adopted to check whether a dialog is researchable or not and how well the usability of a dialog box is.

In this section, a comparison of these assessment ways is presented to readers, which consists of the same and distinct features in evaluating the development process of a system [354]. The common characteristics of the three approaches are shown in the following:

- The evaluation techniques are carried out in a specialist usability laboratory not in users' working environments (fields). Laboratory studies allow the control over users' activities, and field studies can help an evaluation to capture the naturalness of a working environment.
- According to whether a method relies heavily on the interpretation of evaluators, the three assessing techniques mentioned above are regarded as subjective ways. It means that candidates should have extensive knowledge, understand the background and expertise of a certain area of study, and walk through their assessment procedures under the guidance of the aims of this inspection.
- These evaluation techniques support qualitative measurement, which are used to reflect the things that can not be represented by quantitative measurement. An example of this is an assessment to an e-learning tool in which a qualitative question is "The software supports the description of semantic information of learning units and processes in terms of the demands of learners and/or staff.". These methods are non-numeric and can provide important information that can not be determined from numbers. That is, they are high-level inspection ways, such as "Does the tool support users' individualized aggregation of learning units based on various orders and conditions?".

- The evaluation techniques do not influence the way a user works during the process of measurement, as they do not provide immediate response to this user. Users may interpret events in terms of their preconceptions and rebuild their behaviours during the interaction with a system.
- The demand in the equipments used by these evaluation techniques to complete evaluations is on the low level. This can make the assessments performed by these techniques to be cheap and quick.

Next, the main differences between the approaches are described as follows:

- Cognitive walkthrough and heuristic evaluation can be used throughout the development process of a product, but model-based assessment mainly inspects the design stage of this procedure.
- Cognitive walkthrough and model-based assessment provide low-level information, and heuristic evaluation always gives high-level impression of a system. During the development of a tool, the information required by evaluators involves low-level things (e.g. what semantic information of a learning unit needs to be described?) and high-level ones (e.g. Can users integrate the selected learning units according to the new orders and conditions at runtime of a learning process?). Through answering the questions from low level to high level, candidates can give their personal view of a design, prototype, or fully functioning product at different layers.
- The expertise of an evaluator required by cognitive walkthrough or model-based evaluation is higher than what heuristic approach needs. On the one hand, the less limitation that participants' expertises have, the more complex methods that an evaluation can adopt. On the other hand, it is difficult to find a lot of candidates with high expertises. So it is important to select people with appropriate knowledge background that matches with the needs of an assessment.
- The time spent on doing cognitive walkthrough or model-based assessment is longer than the time used to perform heuristic inspection.

Another category of evaluation methods is actual user testing. Here, three evaluation methods are described as follows:

- Experimental evaluation [348] refers to using a set of controlled experiments to assess a design process, prototypes or products. This method is always used to test a hypothesis at different levels of different issues through measuring candidates' behaviours. There are a number of factors that should be carefully

considered in order to design an experimental assessment, such as goals of experiments, objects tested, selection of participants, accurate questions, and a testing procedure.

- Interviews evaluation [349] is a direct method (e.g. by telephone or face to face) to obtain the information from abstract level to concrete level through interviewing people about their interaction with a system. Usually, this approach starts with general questions (e.g. goals of a module) and then moves into more leading questions (e.g. why these goals, why not others.). An interview should be planned in advance, especially designing a series of ventral questions and the relevant details. Also some questions are created during an interview in order to go with the new situations appeared in this interview. Furthermore, according to the different situations of participants, the different levels of questioning are adopted to meet these different context. During an interview, a user is guided to walk longer in his/her interesting questions in order to get more details.
- Questionnaire evaluation [350] is a method with fixed questions in advance, in which candidates always fill in a survey by themselves. The key point of this approach is the design of questions, which asks survey designers should have broad and deep knowledge background on the area that will be checked. In addition, the questionnaire is often asked to be pilot tested.

The following sentences show the same and different aspects of these three methods in assessing a design or products [354]. The main common point of the approaches is that all of them can be used at any stage of a development. The major differences are described as follows:

- Experimental evaluation is mainly used in a laboratory environment, and yet the ways of interview and questionnaire can be suitable for the demands of laboratory or users' different working environments.
- Experimental evaluation supports objective testing on a system, however interview and questionnaire methods are regarded as subjective ways.
- Experimental evaluation does quantitative measurement for a development, yet interview and questionnaire can do both quantitative and qualitative testing.
- Experimental evaluation can provide both high-level and low-level information to evaluators, but interview and questionnaire mainly support high-level information.

- The expertise of candidates required by experimental evaluation is higher than what interview and questionnaire demand.
- Experimental evaluation always influences the way a user works as the immediate responses to this user during the interaction with a system are available. Interview and questionnaire do not.

## *Appendix E---The Handout for the Case Study*

1. In this evaluation, there are four e-learning systems needed to be assessed: the flexible VLE, LAMS, RELOAD, and WebCT. One aim of this study is to check whether these tools can support flexible e-learning or not. Another goal is to find the restrictions of the systems in flexibility such as designer/learner models, learner control, teacher customisation, and pedagogy (see evaluation questions).
2. The flexible e-learning refers to meeting the personalized requirements (flexibility) of students and teachers on the Web, such as creating various electronic learning processes according to the different demands of students.
3. Traditional education is education in classrooms not on the Web.
4. Learning units refer to digital resources that can be reused and shared by users, such as a lecture, a presentation, an electronic book, a Web page, or an exam.
5. A learning process also called an educational process is the statement of an individualized learning procedure (e.g. select different learning units and aggregate them in different orders and conditions), which is authored to facilitate learners to master the indicated knowledge, experiences, and skills.
6. Orders refer to the roads moving among learning units.
7. Conditions refer to the requirements that should be met before students continue to do the back learning units, such as a learner should complete the indicated assignments.
8. The creation of various learning processes refers to aggregating the selected learning units in personalized orders and conditions designed by students and/or teachers.
9. The control (coordination) of learning processes refers to implementing the new orders and conditions (required by students and/or teachers) at runtime of learning processes.
10. The semantic information of learning units and processes refers to the semantics of these objects, such as the Web addresses and version numbers of learning units, and whether a learning unit was locked or not.
11. Command teaching style is an educational manner in which teachers control everything in education, such as choosing learning units, designing processes of learning including orders and conditions.

12. Self pace approach supports learners to do their learning by themselves, such as using their preferred learning content, and aggregating the content with their personalized orders and conditions.
13. Guided discovery learning supports teachers to supervise learners during learning, such as setting movement problems by staff, finding solutions by students, and guiding learners to the solutions by instructors.
14. The reciprocal teaching style is an educational method, which can support students to learn and discuss questions in the groups with different subjects. One student can get helpful feedbacks about his or her learning units, processes, and results from other students in the same groups.
15. In the self-evaluation instruction manner, learners are allowed to make the observation assessment of their personality preferences in teaching and learning. Then, the required learning units and teaching strategies are offered by teachers to students to meet the needs of these preferences.
16. The guidance and counselling method is used to enable students to make proper learning and acquire the right skills in terms of their personalized requirements in career. Learners decide learning aims. Teachers design the relevant learning processes through selecting and integrating the proper learning units.
17. Deep learning involves the critical analysis of new ideas, linking them to already known concepts and principles, and leading to understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts.
18. Surface learning is the simple acceptance of information, such as memorizing concepts as isolated and unlinked facts. It leads to superficial retention of materials for examinations and does not promote understanding or long-term retention of knowledge and information.
19. Serialist learners work step by step in a linear way, usually pulling together a complete picture about a learning subject at the end.
20. Holistic learners try to put a whole picture together at the start and fit the details in later. Setting activities to do piece by piece would work well with serialist learners, but would be less effective for holistic learners. A holistic learner might prefer topic-based learning or the freedom to explore on their own within an overall area.

## ***Appendix F---An Example of the Running Scripts Used in the Case Study***

### **The Flexible VLE**

1. This is the flexible VLE. These are learning units. The following is a set of learning processes.
2. Here, a teacher or a student selected “Lecture 13”, “Lecture 16”, and “Lecture 20”. Click the button “Assemble the Selected Learning Units”. A dialog box appeared.
3. Click the button “Select”. Another dialog box appeared. Select the learning unit “Lecture 16”.
4. Click the button “Ok”. Then click the button “Receive”. The selected learning unit appeared in this area.
5. Lock this learning unit. It means that students need permission to open this learning unit. Also students can not read the content of this test.
6. Click the button “Select”. A dialog box appeared. Select “Lecture 13”.
7. Click the button “Ok”. Then click the button “Receive”. The selected learning unit appeared.
8. Lock this learning unit. Select “In front of” between the two units.
9. Click the button “Save and Refresh”. These learning units and their orders and conditions were stored.
10. Click the button “Select”. A dialog box appeared. Select “Lecture 13”.
11. Click the button “Ok”. Then click the button “Receive”. The selected learning unit appeared in this area.
12. Lock this learning unit.
13. Click the button “Select”. A dialog box appeared. Select “Lecture 20”.
14. Click the button “Ok”. Then click the button “Receive”. The selected learning unit appeared.
15. Lock this learning unit. Select “In front of” between the two units.
16. Click the button “Save and Refresh”. These learning units and their orders and conditions were stored. Click the button “Ok”.
17. Click the button “Create Learning Processes”. A dialog box appeared. Input a name for this learning process: F1. Click the button “Auto Set”. The system automatically gave a unique version number for this learning process.

18. Click the button "Select". A dialog box appeared. Select "Lecture 16". Click the button "Ok". Click the button "Receive Selected Learning Unit". "Lecture 16" appeared in this area. Click the button "Save and Refresh". "Lecture 16" was aggregated into the learning process "F1".
19. By using the same way, "Lecture 13" and "Lecture 20" will be aggregated into "F1".
20. Click the button "Ok". The main window appeared. Here, we can see the learning process "F1" with the orders and conditions. Select "F1". Click the button "Run".
21. A dialog box appeared. Select "F1". Click the button "Ok". A learning environment was presented to a student.
22. Select "Lecture 20". Click the button "Open". A dialog box appeared to show that the student needs permission to learn this unit.
23. Input the name of the student. Click "Ok". A dialog box was presented to the teacher. If the teacher clicked the button "Pass", "Lecture 20" would be opened for the student. If the teacher clicked the button "Fail", the student can not open "Lecture 20" because he/she didn't pass the test.
24. Now the teacher clicks the button "Fail". A dialog box appeared to tell the student who didn't get the permission. Click the button "Ok". Select "Lecture 20". Click the button "Open". We can see "Lecture 20" can not be opened. Click the button "Ok".
25. Select "Lecture 16". Click the button "Open". Get the permission from the teacher. Now select "Lecture 16". Click the button "Open". "Lecture 16" was opened for the student.
26. Ok. The running procedure of the flexible VLE was completed.