MULTI-CRITERIA BASED NEGOTIATION FOR LEARNING CONTENT SELECTION

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Abstract

With the rapid evolution of information technology and continuous expansion of all sorts of content on the internet, enormous opportunities have become available for learners to enhance their learning. Consequently, learners need effective support mechanisms that assist them in efficiently selecting the most appropriate learning content for achieving their learning goal, rather than blindly grabbing materials that are largely available on the internet.

However, it is a challenging problem to provide appropriate learning content selection facilities for the learners to efficiently identify learning content that best suit their needs, due to the large varieties of the factors that influence the process of learning content selection. Previous research has presented various solutions targeting the facilitation of learning content selection. Many of them provide content selection rules by simply grouping learners into different pedagogical categories merely based on limited theories or designers' own judgments. Disadvantages of these approaches are obvious: the lack of comprehensive supports of pedagogical theories reduces the preciseness and reliability of the content selection results.

Based on the literature review regarding the factors that influence learning content selection, standardized educational metadata, and current computer software technologies, this project therefore proposes a web based interactive system for learning content selection by introducing a multi-criteria decision making methodology. Based on the methodology, a mechanism for matching learning content with subject matter characteristics of the learning resources and learner's preference is developed. By taking dynamic and interrelated parameters as user inputs, recommendations for the content selection are generated based on the built-in parameter dependency rules.

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Chapter 1 Introduction

1.1 Introduction

This chapter first presents a brief introduction of the research background and specifies the motivation of this thesis. Then the design objectives of this project are discussed, followed by the outlines of the research. Finally, the overall structure of the thesis is presented.

1.2 Background

While performing learning, it is self-evident that the learners need to obtain the most appropriate training content in order to effectively achieve their learning goals. However, the selection of the electronic learning content is considerably difficult, because the amount of the potential learning content that is available on the internet is tremendous. It is a complex and time consuming process for the instructors to artificially identify the most suitable learning content that fulfill the individual learner's needs within this huge amount of learning resources. Especially, in the self-guided learning situation, if the learners have to autonomously find the learning content that best suits their need, the problem is even more severe. It is highly possible that the learners could access the content that is of little use and not appropriate for the subjects of interest at all. Therefore, a need exists to develop a mechanism to assist learners in reducing the learning content searching space and at the same time, to help learners in more efficiently selecting learning content that best satisfy their requirements.

To achieve the successful development of such a mechanism for effective and efficient learning content selection, a diverse range of factors that influence the process of content selection need to be considered. These factors could be individual's learning preferences, knowledge of the domain to be taught, characteristics of the learning resource itself, and so on. The learning content selection could then be considered as the process and consequence of the concurrent collaboration of these influential factors. As a result, how to address the correlations among the relevant factors and associate them with the learning content is a crucial step in the development of learning content selection system. Following this idea, solutions have been designed to offer the assistance for learning content selection. However, many attempts are facing a basic problem, which is the lack of support for proven pedagogical theories and instructional principles. This design limitation directly leads to the weak educational offering of the developed system. The major endeavor of this thesis is therefore to address the problems stated above, and develop a multi-criteria based learning content selection framework that is underpinned by proven theories. As the consequence, a web-based learning content selection system driven by the proposed framework is implemented by using current state of art web technologies, so as to provide an effective tool for learners to more easily select appropriate learning resources that suit their needs.

1.3 Objective of the Research

The selection of learning content is the most essential step for any learning process. An adaptivity enabled learning content selection system can remarkably improve the efficiency of the content selection process. The implementation of such a learning content selection system is not as easy as it sounds to be. One of the major reasons is, as descriptive variants, factors such as the attributes of the learning content, the learner's preferences, characteristics of the learning domains, and so on will notably influence result of the learning content selection. More importantly, these influential factors are largely diverse. It is very difficult to determine, without the support of proven instructional theories, which of and how these factors can effectively influence the learner's selection. Therefore, this project attempts to address this problem by developing a learning content selection system on the basis of a multi-criteria based negotiation mechanism.

The key objectives of this research are summarized as follows.

- Based on the proven pedagogical theories, develop a content selection framework with multiple correlated criteria to address the various influential factors during learning content selection.

- Implement a web-based learning content selection system based on the proposed multi-criteria framework, so as to offer a negotiating environment for assisting learners to more efficiently select suitable learning content.

1.4 Research Outline

As a whole, the research is conducted in six steps, which can be conceptually divided in four main sections: background research, concept design, prototype system implementation, and evaluation.

1. Review current educational literature to confirm the overall range of the influential factors that is pedagogically relevant to the learning content selection.

2. Investigate the current educational metadata standards, and adopt appropriate elements as the criteria for describing the unit of a learning content.

3. Based on the extensive review of instructional and psychological theories, identify the correlations between each parameter, and build dependency rules for the parameter.

4. Review related web development technologies, and design the system architecture.

5. Implement a web-based learning content selection system based on the identified parameters and their dependency rules.

6. Evaluate the implemented content selection system.

Figure 1 illustrates the research outline of the thesis.

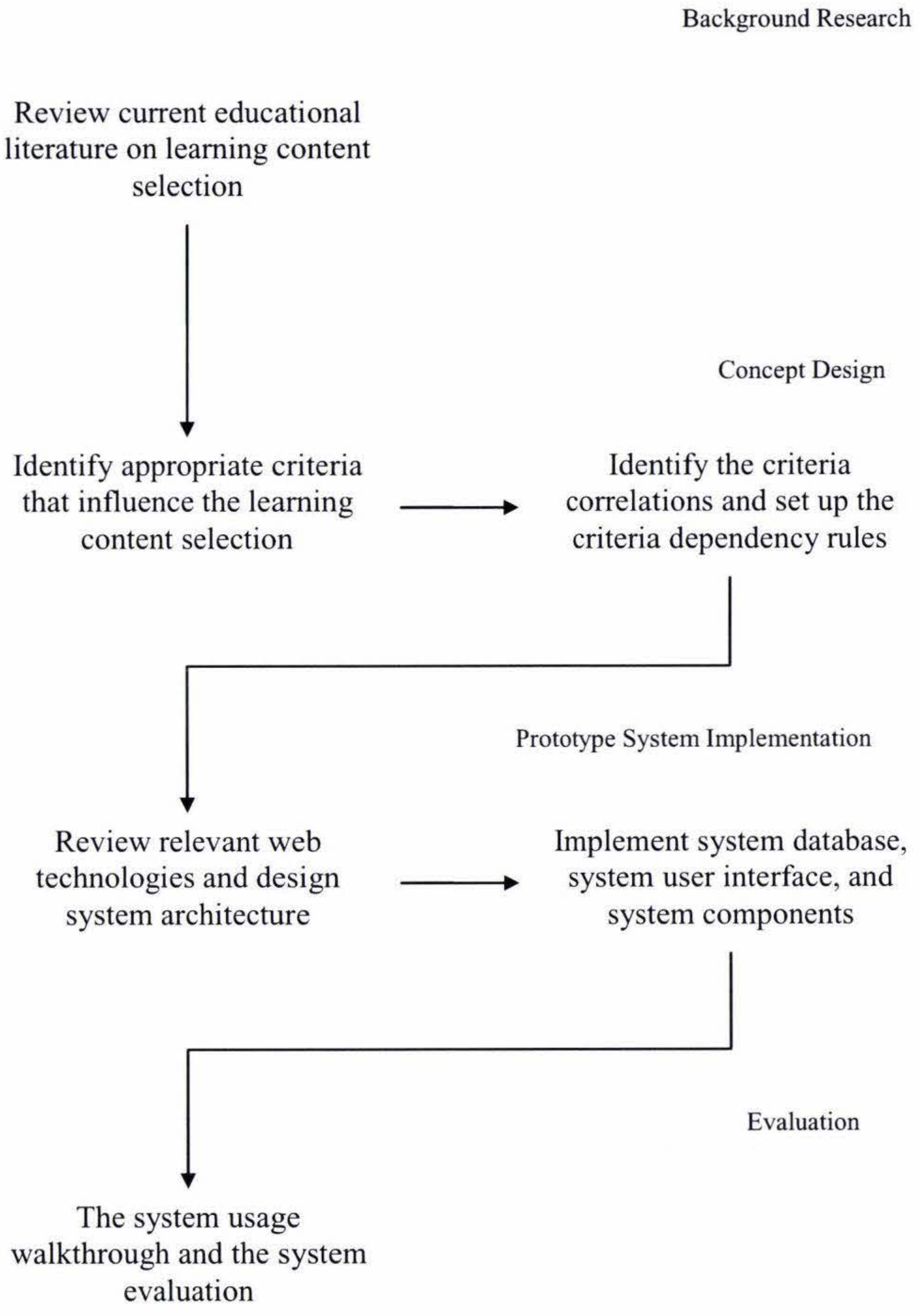

Figure 1 the Research Outline

1.5 Structure of the Thesis

Based on the research outline, the thesis is organized in 7 chapters, which are listed below.

Chapter 1 provides a general introduction that mainly covers the motivation, objectives, and overall structures of this research.

Chapter 2 provides a comprehensive literature review that is relevant to the learning content selection. The review includes the relationship between content selection and educational systems, relevant instructional theories, and current development of various educational metadata standards.

Chapter 3 presents the details of the framework concept design and analysis. Based on the literature review, the identification of appropriate criteria and the development of the criteria dependency rules are carried out.

Chapter 4 depicts the detailed process of the system implementation, which includes the reviews of the adopted technologies, system database design, system architecture design, and the development of system components.

Chapter 5 mainly describes the deployment of the implemented system, and presents a comprehensive walkthrough to demonstrate the usage of the prototype system.

Chapter 6 presents the evaluation of the implemented system, and analyzes the feedback gathered from the evaluators.

Chapter 7 draws the conclusions for the research based upon the results of the system evaluation.

Chapter 2 Literature Review

2.1 Introduction

This chapter presents relevant literature review concerning learning content selection in the context of educational systems. The first section of the literature review gives a brief introduction of intelligent educational systems, including basic concept and overall structure. Then the relationship between learning content selection and the intelligent educational system is presented, followed by the discussion of different content adaptation approaches. This is followed by the section that investigates possible variants that are effectively adopted when selecting learning resource in Web-based adaptive learning environments. Finally, in the last section, the discussion is focused on the role that Metadata standards play in adaptive learning content selection.

2.2 Learning Content Selection in Educational Systems

According to ADL (2001), learning content in its most basic form is composed of assets that are electronic representations of media, text, images, sound, web pages, assessment objects or other pieces of data that can be delivered to a Web client. Early existing Web-based educational systems typically consisted of a series of static hypertext pages containing all sorts of individual piece of learning content (such as pictures, sounds, text, and so on). This has been a big obstacle to learners when they want to obtain materials that best fulfil their need, because the static systems only offers a "one size fits all" approach for content delivering, and lack means to tailor learning content to meet a specific learner's demands. In recent years, challenging research has been focused on the development of advanced Web-based education applications that make learning content adaptable to learners and knowledge domains. For this purpose, research on Web-based Adaptive & Intelligent Educational Systems has become a hot research and development area.

2.2.1 Adaptive Intelligent Educational Systems

The adaptive intelligent educational systems provide an alternative to the traditional "just-put-it-on-the-Web" approach in the development of Web-based educational courseware (Brusilovsky & Miller, 2001). Compared with traditional learning content delivering approaches, the adaptive intelligent educational systems offer the potential to uniquely address the specific learning goals (Kaplan et al., 1993), prior knowledge (Milosavljevic, 1997) and context of a learner so as to improve the learner's satisfaction with the learning content. Specifically, the adaptive intelligent educational systems realize the adaptivity by establishing a model of learning goals, learner preferences and knowledge of each individual learner and then using these models during the interaction with the learner in order to satisfy the learner's demands. Besides, the adaptive systems also achieve intelligence by incorporating and presenting instructional activities that are traditionally performed between learners and human teachers.

Although there are many types of adaptive intelligent educational systems with diverse structures available, five typical components can be identified in general. They are the learner model, the domain knowledge module, the pedagogical module, the expert model, and the communication (user interface) model (Burns & Capps, 1988; Brusilovsky, 1994).

- The *learner model* contains important information about the learner during the learning process, such as learner's prior knowledge, behaviour history, personal characteristics and preferences, and so on.

- The *domain module* contains all characteristics of knowledge to be taught.

- The *pedagogical module* decides *what*, *how* and *when* to teach the domain module content, taking appropriate pedagogical decisions according to the user needs.

- The *expert model* contains rules and theories of specific learning domain to be transmitted to the learner. Usually, these rules are based upon experts' perspectives.
- The *communication (user interface) model* is mainly responsible for facilitating the communication between learners and the educational system.

Figure 2-1 demonstrates the general view of the five typical components and their interactions within an adaptive intelligent educational system:

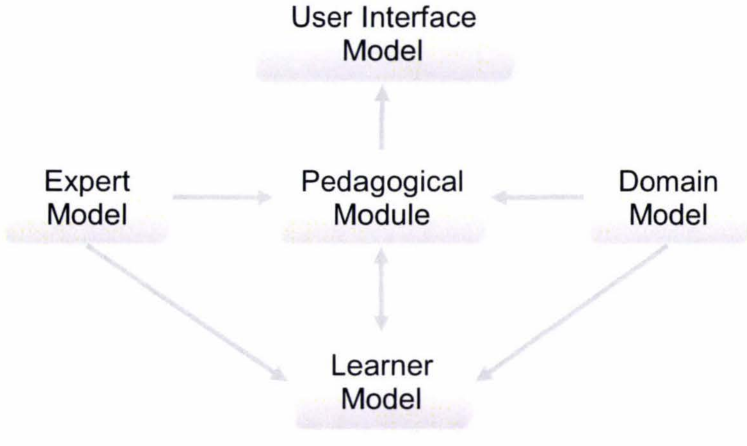

Figure 2 Common Components of Adaptive & Intelligent Educational System

In spite of the variety of components in the system, all of their development goals fall into one purpose – how to provide learners with the learning content that most suit their requirements.

2.2.2 Matching Content to Delivery

The most crucial aspect in the development of an intelligent educational system is how related knowledge is represented and how reasoning for decision making is accomplished (Ioannis & Jim 2005). For this purpose, the learning content adaptation needs to be applied. To effectively adapt learning materials to the learner's needs, on the one hand, knowledge about the learner, subject, and content should be precisely modelled by the system, and on the other hand, the system needs to mimic corresponding human decision making as much as possible.

Existing Web-based learning systems use different types of adaptation techniques (Brusilovsky, 1996). These techniques comprise adaptive presentation and adaptive navigation, curriculum sequencing, intelligent solutions analysis, interactive problem solving support, and adaptive information filtering (Brusilovsky & Christoph, 2005; Weber, 1999).

- The *adaptive presentation* adapts the content of hypermedia page to the learner's goals, knowledge, and other information stored in the user model. In a system with adaptive presentation, learning content is not static but adaptively generated or assembled from different pieces for each learner according to their model context.

- The *curriculum sequencing* provides the learners with the most suitable, individually planned sequence of knowledge units to learn and sequence of learning tasks (examples, questions, problems, and so on) to work with. In other words, it helps the learner to find an "optimal path" through the learning material.

- The *adaptive navigation support* assists the learners in hyperspace orientation and navigation by changing the appearance of visible links. By adopting this technique, the system can adaptively sort, annotate, or partly hide the links of the current page to simplify the choice of the next link. It also shares the same goal with curriculum sequencing – to form an "optimal learning path" for the learner through learning content.

- The *intelligent solution analysis* provides the evaluation for learners' final solution to educational problems. It analyses errors in the answers and points out exactly what is wrong or incomplete and which missing or incorrect piece of knowledge may be responsible for the errors.

- The *interactive problem solving* provides the learners with intelligent help on each step of problem solving - from giving a hint to executing the next step for the learner. The systems that implement this technique can watch the actions of the learners, and use the understanding of the learners' action to provide help and to update the learner model as well.

- The goal of the *adaptive information filtering* is to find a small numbers of learning items that are relevant to learners' interests in a larger pool of resources, so as to considerably reduce the searching space of learning content from huge amount of learning object repositories. The term "learning object" here is referred to as any entity, digital or non-digital, which can be used, reused, or referenced during technology-supported learning IEEE (2002). According to ADL (2001), learning objects are aggregated into learning content that can be used to address specific learning objectives.

2.2.3 The Role of Content Selection in Educational Systems

Some of the tasks that any e-Learning platform should carry out and that characterize the whole training process are to allow people involved in training to find, evaluate and acquire content, to allow easy updating and maintenance of both content and information about users and to create content tailored to each learner (Cirillo et al., 2000). Not only the traditional (human based) learning resources delivery process can be facilitated by the adoption of adaptation techniques inspired learning content selection, but also the selection of content plays a significant role in diverse adaptive intelligent educational systems. Especially, the content selection is strongly related to various types of adaptation processes, such as adaptive navigation, adaptive course sequencing, and adaptive information filtering.

The selection of learning content could be considered as the initial step to perform *adaptive navigation* and *adaptive course sequencing*. According to Knolmayer (2003), adaptive course sequencing is defined as a process that selects learning content from a digital repository and sequence them in a appropriate way to suit the targeted learning community or individual learner, whereas the adaptive navigation is described by Brusilovsky (1999) as an extension of curriculum sequencing into a hypermedia context, and provides a mechanism to adapt selected content to student goals, knowledge, and other information stored in the student model. Before the actual navigation or sequencing is started, both adaptation processes involve the discovering and selection of learning content in advance from various sources. Therefore a quality pre-selected content set could eventually facilitate the further adaptation process.

Compared with the adaptive navigation and adaptive course sequencing, the most significance of adaptive learning content selection is to realize the *adaptive information filtering*. As the amount of both on-line and off-line learning objects is increasing exponentially, the content selection process would require a significant computational time and effort. This becomes more apparent when learners need to autonomously find training content that best suit them. The key aim of the adaptive information filtering technique is to minimize the searching space of available learning content, so as to avoid the possibility of accessing useless and subject interest unrelated content. Therefore, there is strong implication that whether an educational system can provide efficient content adaptation is highly related to how the learning content searching ranges are narrowed down.

2.3 Factors that Influence Learning Content Selection

Recent practices of adaptive learning development show that the consequence of adaptive learning content selection is explicitly affected by various factors. These factors widely range from media type characteristics of the learning content itself (such as format, duration, and so on) to pedagogical parameters of the learner's preferences (e.g. learning style, collaboration, timeliness, and so on). Within these diverse criteria, some can be found trivial for contributing pedagogical hints to support instructional decisions making, while some are proven to be remarkable for building effective pedagogical rules. More importantly, the parameters are not isolated from each other, strong interrelations and dependencies exist among them. Hence, in order to achieve better adaptabilities of selected learning content, the content selector should identify appropriate descriptive criteria and properly handle the associations between them, rather than simply grab values from them.

Various researches (such as Brusilovsky, 1998; Rousseau et al., 1999; Brusilovsky, 2002, & Souto et al., 2002) imply that, in order to achieve adaptivity in educational system, issues as regards how the learner's profile and the knowledge about the domain are modeled needs to be taken into consideration. The learner's profile offers the system with the information about the educational characteristics of the learner's cognitive preferences, such as collaboration, learning style and timeliness and so on, while the knowledge about the domain takes the pedagogical characteristics of target learning domain into consideration, and makes the adaptive content selector understand what type of instructional material is preferred for that particular domain. Hence, from a pedagogical angle, the learner profile and the knowledge domain form the most significant criteria for content selection, and the selection process is mainly performed under the simultaneous collaboration of these factors.

2.3.1 Learning Theory

As described above, the knowledge about the domain is considered to be a key aspect for achieving adaptive content selection. How to explore the instructional characteristics of learning domains and its associations with specific learning materials heavily relies on widely recognized learning principles or theories. This point is further depicted by Ciaffaroni (2006) that pedagogical decisions on learning are usually made according to a well grounded framework, within which the most relevant learning theories are mapped.

2.3.1.1 What is Learning Theory?

Burns (1995) conceived of learning as a relatively permanent change in behavior with behavior including both observable activity and internal processes such as thinking, attitudes and emotions. The learning theory could be considered as a set of constructs linking observed changes in performance with what is thought to bring about those changes. It provides empirically-based accounts of the variables which influence the learning process, and provide explanations of the ways in which that influence occurs (Calvani et al., 2006).

Since early 20th century, more than fifty theories that are relevant to human learning and instructional design have been devised by various psychological, educational theorists. Although the principles and applications for instruction reflected from these theories are diverse, most of these theories can be categorized into three broad educational ranges: behaviorism, constructivism, and socio-cultural, which are listed as following (Palmer, 2001; Ciaffaroni, 2006).

- The *behaviorism* is also known as "learning as an activity". It based on observable changes in behaviors. Behaviorism focuses on a new behavioral pattern being repeated until it becomes automatic, and also emphasizes on how reinforcements and punishments in the environment shape behaviors.

- The *cognitivism* is known as "learning as achieving understanding". It is based on the process of thoughts behind the behavior. Changes in behavior are observed and used as indicators to show what is happening inside the learner's mind. Basically, the constructivism attempts to understand how information that comes through the senses gets processed, stored, and used.

- The *constructivism (socio-cultural)* is known as "learning as a social practice". It shifts the focus from the analyses of learning to the social context in which learning takes places, and stresses the problem solving process in ambiguous social situations.

Furthermore, with the constant evolution of the theories, numerous models for learning have been proposed. These include Kolb's experiential learning cycle (Kolb, 1984), Jarvis' model of reflection and learning (Jarvis, 1987), and Barnet's framework for higher education (Barnett, 1990). Each model has a different focus and emphasis, with which the model can be used to guide specific aspects of learning in a particular learning domain context.

2.3.1.2 Why Use Learning Theory?

According to Newby et al. (1996), the investigation of pedagogic concerns involves researching various ideas in instructional practices. Inadequate considerations of pedagogical requirements cause the failing design in the field of educational development. Although technology driven instructional approaches are getting prevalent for the development of educational systems, the pedagogic concerns are still playing greater part than the medium technology does for knowledge delivering. If the pedagogic concerns are not well considered, the learning system will still end up with inutility or be useless to the learner. To achieve the overall usability, the system should deliver instructional materials in a meaningful and supportive manner, rather than merely dump knowledge to learners. For this purpose, taking learning theories into careful consideration should be a major inspiration in the development of educational system.

Recent researches are beginning to put more focus on the consideration of adopting theories of learning when developing instructional systems. This is also due to some other pedagogical significance of the learning theory. First of all, established learning theories in a way could be seen as the source of verified pedagogical strategies, because they were accumulated by various well known scholars or psychologists based on the long term learning experience. Principles reflected from such solutions are crucial when instructional designers seek to select an effective recommendation to solve specific aspects of a learning problem. Secondly, learning theories offer the basis for articulation and intellectual pedagogical decision making. According to Keller (1979), learning theories usually offer information about associations between instructional module and the learning design. This information can supply implications on how specific teaching/learning techniques, resources, or strategies best suit target educational circumstance and specific learners. Lastly, the most significant role that the learning theory plays for the pedagogy design is to achieve the reliability of instructional prediction (Richey, 1986). Building sensible solutions to instructional problems are often limited by many factors, such as resources, time, expert knowledge, and so on. Therefore, it is vital to ensure that the chosen instructional principles or guidelines have the highest possibility to achieve a successful design under the constriction of these factors.

2.3.2 Learning Style

Most educators agree that, in the design and development of educational material, attention must be focused on learner requirements and characteristics, defined in terms of content and of learning styles (Felder & Silverman, 1988; Larkin-Hein & Budny, 2001, Corso, 2005). Incorporating various learning style theories in instructional design is gaining more and more popularity. Human learning style theories have been broadly studied by enormous researches, and have formed a well-established field within the discipline of cognitive psychology. It is under this circumstance that effectiveness of adoptions of the learning style theory in instructional design is guaranteed.

2.3.2.1 What is Learning Style?

An individual's learning style can be defined in various ways, According to the definition given by Keefe (1979), the learning style is considered as a "composite of characteristic cognitive, affective and psychological factors that serve as relatively stable indicators of how a learner perceives, interacts with and responds to the learning environment", while James (1995) described the learning style as "a complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn", and further, Sarasin (1998) defined the learning style as the "preference or predisposition of an individual to perceive and process information in a particular way or combination of ways". In spite of the variety of definitions, the basic principle behind the learning style theory is straightforward – "different people learn best in different ways". Although there is huge amount of research focusing on learning style, no evidence shows there is any agreement or acceptance of any one theory (Bruen et al., 2001).

2.3.2.2 Why Focus on Learning Style?

As figure 2-2 shows, the way that learners learn could be affected by many factors. A learning style that pre-matched with the learner's characteristics can offer a particularly efficient way for that learner to learn. For example, when learning a second language, a learner who prefers practical exercises would like to start face to face conversation immediately rather than go through the tedious grammar first, while some other learners just prefer the contrary way. Most educators agree that "learning styles exist and acknowledge the significant effect that learning styles have on the learning process" (Vincent & Ross, 2001). There is also a general agreement that the most effective learning occurs when the learning activities most closely match the learner's preferred style. By matching the instruction methods with various learning styles of the learners, unsuitable learning activities could be avoided, and a relatively comfortable and easy learning procedure could be undertaken.

Figure 3 Factors of Influencing the Way People Learn (Honey et al., 1992)

2.3.2.3 Models of Learning Style Theory

The school of thought of a learning style is a controversial issue. A theory always has little agreement over another. Everything from the exact definition of learning styles to the very existence of learning styles has been hotly debated (Gordon & Bull, 2004). In spite of the lack of clear agreement regarding the perception of learning style, a considerable amount of the research has been devoted to the development of a series of instruments or models for measuring an individual's learning style. There are hundreds of example models of the learning theory that gauge a series of factors of learning, such as Neil Fleming's *VAK Framework* (Fleming, 1996), Howard Gardner's *Multiple Intelligences* (Howard, 1993), Witkin's *Field Dependant/Field Independent* Model (Witkin, 1954), Soles & Moller's *MBTI* (Soles & Moller, 2001), Kolb's *Experiential Learning Cycle* (Kolb, 1984), and so on. However, practices show that principles of many different theories sometimes contradict with one another. No one school of thought is supposed to be better than the others. All theories are considered to be possible to measure an individual's learning style and preferences according to their particular instruments.

Kolb (1984) provided perhaps one of the most useful descriptive models of the adult learning process, inspired by the work of Lewin (1942). Illustrated as figure 2-3, Kolb's Experiential Learning Style suggests that there are four stages that follow on from each other to complete a cycle of learning.

- The first stage is *concrete experience* where a learner has active experience of learning something.
- Following the concrete experience, the *reflective observation* focuses on personal experience. Then makes sense of rationales behind the experience.
- The third phase *abstract conceptualization* focuses on how the experience is applied to known theory and drawing conclusions.

- In the last stage *active experimentation,* learners use theories to solve problems and make decisions. Finally the learner tests theories in new situations and plans what to do in the future (Harris, 2004; Atherton, 2005).

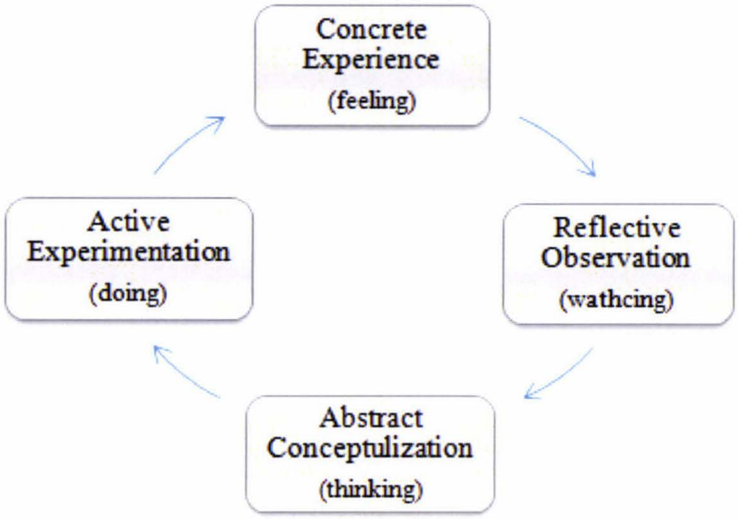

Figure 4 Kolb's Experiential Learning Cycle (Atherton, 2005)

2.3.2.4 Honey and Mumford Learning Styles Theory

Among the competing learning style theories, the Honey & Mumford Learning Style theory has been increasingly put into practical use for measuring an individual's learning style. Honey and Mumford (Honey et al., 1992) defined the learning style as "the attitudes and behaviors which determine an individual's preferred way of learning". They further exploited the four stages of Kolb's Experiential Learning Cycle, and suggested four types of learners - *Activists*, *Reflectors*, *Theorists* and *Pragmatists*, which are roughly corresponding with the experiencing, reflecting, generalizing and experimentation stages of the learning cycle.

- ***Activists***

Activists involve themselves fully and without bias in new experiences. They enjoy the here and now and are happy to be dominated by immediate experiences. They are open-minded, not skeptical and this tends to make them enthusiastic about trying anything new. Activists tend to act first and consider the consequences afterwards. Their days are filled with activity. They tackle problems by brainstorming. As soon as the excitement from one activity has died down, they are busy looking for the next. They tend to thrive on the challenge of new experiences but are bored with implementation and longer term consolidation.

- ***Reflectors***

Reflectors like to stand back to ponder experiences and observe them from many different perspectives. They collect data, and prefer to think about it thoroughly before coming to any conclusion. The thorough collection and analysis of data about experiences and events is what counts so they tend to postpone reaching definitive conclusions for as long as possible. They are thoughtful people who like to consider all the possible angles and implications before making a move. Reflectors enjoy observing other people in action and getting the drift of the discussion before contributing their own opinions and thoughts. They tend to adopt a low profile and have a slightly distant, tolerant and unruffled air about them.

- ***Theorists***

Theorists adapt and integrate observations into complex but logically sound theories. They think problems through in a vertical, step-by-step, logical way. They assimilate disparate facts into coherent theories. They tend to be perfectionists who won't rest easy until things are tidy and fit into a rational scheme. They like to analyze and synthesize. They are keen on basic assumptions, principles, theories, models and systems thinking. Theorists tend to be detached, analytical and dedicated to rational objectivity rather than anything subjective or ambiguous. Their approach to problems is consistently logical. They prefer to maximize certainty and feel uncomfortable with subjective judgments, lateral thinking and anything flippant.

- ***Pragmatists***

Pragmatists are keen to try out new ideas, theories and techniques to see if they work in practice. They positively search out new ideas and take the first opportunity to experiment with applications. They are the sort of people who return from management courses brimming with new ideas that they want to try out in practice. They like to get on with things and act quickly and confidently on new ideas that attract them. Pragmatists tend to be impatient with ruminating and open-ended discussions. They are essentially practical, down-to-earth people who like making practical decisions and solving problems. They respond to problems and opportunities 'as a challenge' (Honey et al., 1992).

Figure 4 illustrates the correspondence of Honey & Mumford's four types with Kolb's four stages:

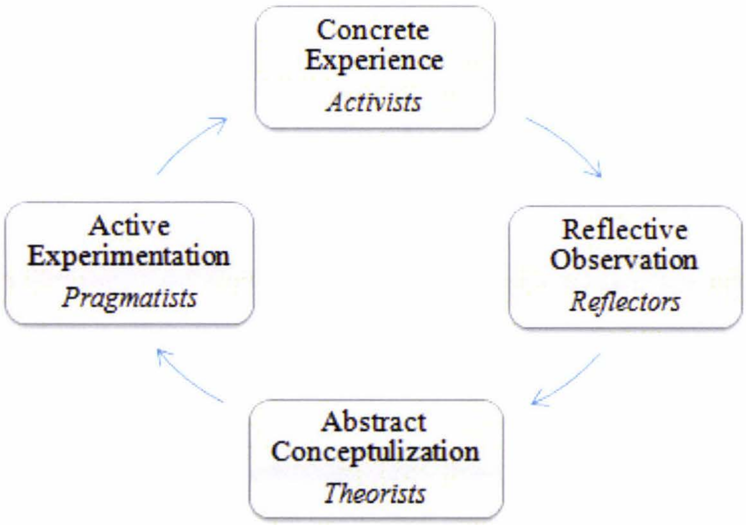

Figure 5 Honey & Mumford Learning Style (Atherton, 2005)

2.3.2.5 Assessment of Individual's Learning Style

Knowing individual differences are particularly crucial to content selection in educational systems, especially in a fully self-guided learning environment. Because within that environment, there is usually no instructor available to adapt the learning content to fulfill a learner's needs. Therefore, that is why an assessment method for identifying individual user's learning style is critical. According to Logan et al. (2002), assessment of learning styles is important for two reasons.

- Assessment provides a reliable and valid way to compare one individual against another.
- Individuals are usually unaware of their own learning style preferences. A proper assessment can match right learning style to the learner, so as to offer appropriate types of learning content that is best for them.

Currently, the most used way to assess learning styles is through self-evaluation questionnaires. These provide researchers as well as educators an easy, reliable and validated way to distribute and assess individual requirements (Cronbach 1990). Honey and Mumford designed an assessment called the Learning Styles Questionnaire (LSQ) based on a simplified version of Kolb's Experiential Learning Cycle. It can be used to help identify one aspect of learners' individual preferences about the way they learn. The questionnaire contains 80 self-evaluation questions, requiring only a positive or negative answer to each. Scores obtained are ranked in relation to their percentiles according to the general norms from a sample of 3,500 individuals. This questionnaire has been widely used for the self-identification of individual's learning style (Honey et al., 1992).

So far, we have discussed various pedagogical theories that related to the influential factors of learning content selection, and elaborated the importance of these theories in regard to the adaptive learning content selection in instructional design. Nevertheless, as much as the pedagogical theories are important, it is also very necessary in educational systems to have learning content described in an accredited and standardized form, so that the content can be properly identified and the adaptation logic can be more easily applied to filter the content appropriately to suit individual learner's needs. To achieve this purpose, the standardization for educational applications has been conducted within the E-learning community in recent years.

Therefore, in next section we will give an overall investigation on the standardization efforts in educational systems.

2.4 Educational Metadata Standards

Since the beginning of the 90s, lots of technology communities and scientific groups have started to devote themselves to the work on a range of additional aspects of standardization and metadata. The devotion is not remained only in the traditional application fields (such as web, multimedia, and so on), but is also significantly focused on the area of e-learning development. As a consequence, the recognition of the potential economies of reusing educational materials spawned the development of metadata standards for sharing and storing learning objects (McClelland, 2003). Therefore the area of educational metadata and standardization has become one of the most researched topics.

2.4.1 What is a Standard?

Normally, standard can be comprehended as a definition or a format that has been widely approved by recognized organizations or been accepted by the industry. For instance, the MP3 format is a kind of standard that can be used to share music; DVD is defined as the industry standard for delivering movies to individual audiences; the HTTP protocol is a de facto standard for transferring data between heterogeneous operating system over the internet. However, the definition of "standard" is diverse depending on the field that the standard applies. As described in IEEE STD 610 (IEEE, 1990), standards are "mandatory requirements employed and enforced to prescribe a disciplined uniform approach to software development, that is, mandatory conventions and practices are in fact standards". More concisely, standard is just "a pattern or model that is generally accepted" (Cambridge, 2006).

In the context of education, standard can be considered as a set of criteria for describing instructional materials, a group of voluntary guideline for guiding the pedagogy design, and a series of best practice for conducting the development of the educational systems.

2.4.3 Why Use Standards?

Generally, the main reason for applying standardization in industries is to improve the interoperability. By utilizing standards, communication and collaboration between different systems or components can be more easily achieved. In order to promote use of learning content, identification of appropriate learning material needs to be accommodated. For this purpose, we require a standardized searchable description for the learning content.

From the educational perspective, the significance of using standards is more than just achieving the interoperability. According to Duval (2001), there are few more reasons for adopting standards in the development of educational systems:

- *interoperability*

The interoperability enables reuse of tools and content across functions (cataloguing, discovery, etc.), levels (simple to complex), semantic and linguistic barriers, and technology platforms.

- *open base infrastructure*

Standardizations are needed in order to develop an open base infrastructure where components can be plugged into, because of the wide diversity, and the lack of consensus on a universal best solution. It is also a requirement for large-scale deployment of learning technologies, as it prevents users from being locked into proprietary systems.

- *competition & collaboration*

The standard itself does *not* impose any particular implementation. Rather, as a common specification, it establishes an opportunity for competition or collaboration by diverse communities or groups.

- *permanency*

Standards can help to establish a base technology infrastructure with permanency. This is also a high priority need in educational field: many notable results of R&D projects from the early years are becoming obsolete, because the tools and the equipments that they rely on no longer exist or are not maintained. Without such permanency of technology, we will not be able to build upon the results of our predecessors to achieve progress.

- *credibility*

Standards are produced by 'accredited' organizations, that guarantee an open, fair, transparent and inclusive process, and that take care of the maintenance of the standards. Rather different from these 'de facto' standards that are based on specifications made by an individual, group, or company.

2.4.2 Standardized Metadata

Metadata is specific information to describe other data. A metadata record consists of a set of attributes and elements used to describe a given resource, whether digital or non-digital. An example of library catalog can further depict the idea of metadata. The library catalog itself is just data. It contains the information that a librarian can use to efficiently manage books or journals, and that a user can use for searching material about a particular subject and finding information. Having information about the content, autbor, or legal conditions makes it easier for humans and computers to classify a resource. According to Steinacker et al. (2001) metadata can be used for following purposes:

- Summarizing the meaning of the data

- Allowing users to search for the data based on different aspects of the resource
- Allowing users to determine if the data satisfies intended requirements
- Giving information that affects the use of data (legal conditions, size, age, etc.)
- Indicating relationships with other resources

A metadata is organized into categories or fields that represent a characteristic of the learning resource and add information to the data. This process cannot be arbitrarily carried out; otherwise one runs the risk of creating contradictions and incompatibility (Colace et al., 2003). By taking the describable and discoverable characteristic of the metadata into account, educational communities and standardization organizations incorporated metadata with various established educational standards, so as to not only make the descriptive information of a specific resource human readable, but also to make it identified, processed, and shared by computers in a standardized and authoritative manner.

As is addressed by Corso et al. (2003), the educational metadata standard is mainly developed to achieve three objectives:

- *To address the learning content*

When choosing learning content to learn, the user usually acquires information about different aspects of the content in advance. The standardized metadata facilitates this process by providing a structure of defined elements that describe, or catalog the learning resource, along with requirements about how the elements are to be used and represented.

- *To address the user process*

Not only does the metadata standard describe learning content, but it also provides a standardized framework to illustrate how a teaching-learning process (pedagogy) is designed in a formal way.

- *To address the production process*

The metadata standard can also address the way in which the technologies are used to develop and deliver educational content.

2.4.3 Current Metadata Standards for Education

Having the same purpose of identifying appropriate learning material through a standardized way, thousands of initiatives and projects have been proposing and developing huge amount of metadata specification deriving from different standards worldwide. It seems almost impossible to investigate all of these specifications due to the incredible numbers. However, the survey on several well known standards and their related specifications would be substantial to support the idea of this research.

In spite of the large numbers of metadata specifications established by various communities, we can still identify some major metadata schemas for education, such as IEEE Learning Object Metadata (LOM), IMS (Instructional Management Systems), Dublin Core, ARIADNE (Association of Remote Instructional Authoring and Distribution Networks for Europe), ADL SCORM (Sharable Course Object Reference Model), GEM (Gateway to Educational Materials), AICC (CBT guideline), EDNA, EUN SchoolNet, and so on. Among these diverse schemas, the IEEE LOM and the Dublin Core are widely considered to be the most important metadata schemas for describing learning content according to Fischer (2001). This has been further proved by the fact that, lots of today's metadata application profiles produced by various communities are largely based on both the Dublin Core (such as EDNA, EUN SchoolNet, and GEM) and the LOM specification (such as IMS, ARIADNE, and ADL SCORM). Further, specifications such as EML (Educational Modeling Language) and ELM (Essen Learner Model) are specifically developed to dedicate themselves to aspects (pedagogical, didactic, economic, and professional) not or hardly covered by LOM.

Originally, Dublin Core was a set of 15 metadata elements intended to facilitate description and discovery of electronic resources in a general sense. However Dublin Core has been gradually used for the description of learning content due to its relatively simple structure. Pretty much on the contrary side, LOM was initially built specifically for the educational purpose, and then is gradually more and more applied outside of this original field. LOM is developed to facilitate search, evaluation, acquisition, exchange, sharing and use of learning objects by learners or instructors (IEEE LTSC, 2005). Compared with Dublin Core, LOM provides a far richer structure with more details for 'semantically interoperable' and pedagogically relevant metadata on learning objects (Duval, 2001).

2.4.4 Learning Object Metadata

As one of the most promising metadata approaches for describing learning resources, LOM was developed by the IEEE Working Group P1484.12: the Learning Object Metadata (LOM) Scheme. Originally, the development of LOM was mainly influenced by the work of the Educom's IMS project and the ARIADNE Consortium under the auspices of the IEEE LTSC Committee. Now it has become the world's first accredited standard for e-learning, by being moved to the full ISO standard. LOM is meant to provide a semantic model for describing the learning objects themselves, rather than dealing with matters of how these learning objects may be used to support learning; it specifies the legal value and semantics of each metadata element, its dependency on others, and how metadata elements are composed into a larger structure (Suthers et al., 2001). As an international metadata standard, LOM does not provide any details for implementations of metadata. It only specifies the syntax and semantics of learning object metadata. Works on actual implementations of metadata and other standards are mainly conducted by different consortiums (such as ADL, AICC, ARIADNE, IMS, and so on). According to IEEE LTSC's description, LOM focuses on the minimal set of attributes needed to allow these Learning Objects (LO) to be managed, located, and evaluated. The standard accommodates the ability for locally extending the basic fields and entity types, and the fields can have a status of obligatory (must be present) or optional (maybe absent). This allows practitioners from various local communities to specify mandatory or core elements of their own to meet the particular requirements.

LOM has been devised to enable end users to identify and locate in a more effective and efficient way. It provides a set of meta-data categories of hierarchical structure with which learning objects can be characterized. The general structure of the LOM specification consists of nine categories that group different characteristics of learning objects. Figure 2-5 shows various categories of IEEE LOM specification.

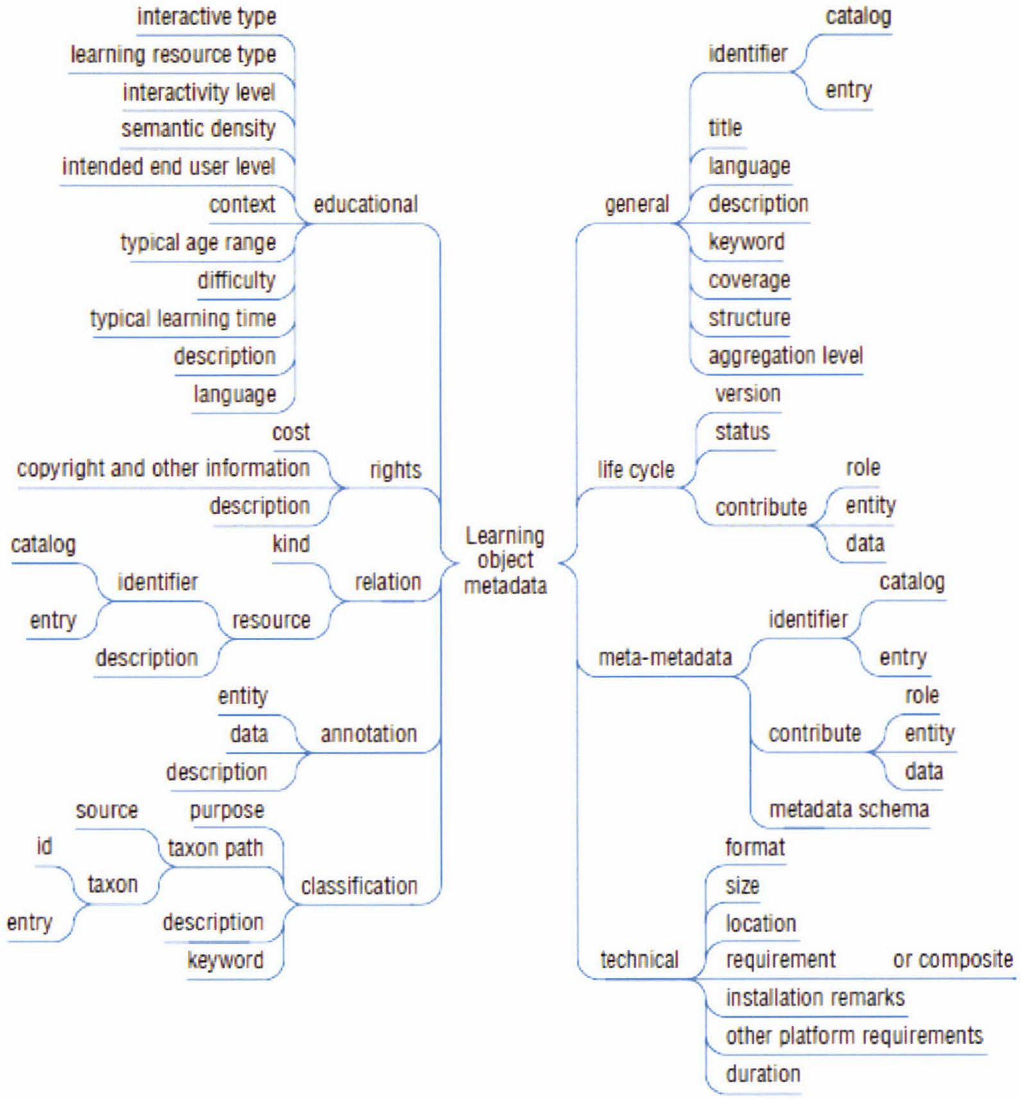

Figure 6 the IEEE LOM Specification

- The *General* category groups general information that describes the learning object as a whole, which includes elements that indicate an identifier for the learning object.

- The *Lifecycle* category consists of the features related to the history and current state of the LO. It includes information on the status and version of the LO.

- The *Meta-Metadata* category groups information about the descriptive metadata itself.
- The *Technical* category specifies the technical requirements and characteristics of the learning object, such as its format, size and location.

- The *Educational* category is devoted to the educational and pedagogical characteristics of the learning object. These data elements are as follows:

    - The *interactivity type* determines whether the LO is more suited for active or passive learning.

    - The *resource type* stands for specific kind of learning content, such as instance exercise, simulation and questionnaire.

    - The *interactivity level* means to what extent a content interacts with the learner (on a scale from low to high).

    - The *intended end user role* means who uses the material (teacher, author, learner or manager).

    - The *semantic density* represents the granularity of particular learning content (on a scale from low to high).

    - The *context* represents the scope in which the learning content is used (school, higher education, training or other).

    - The *typical age range* refers to the learner's developmental age, if that would be different from chronological age.
    - The *difficulty level* indicates how hard a learner could work through the learning content (again on a scale from low to high).
    - The *description* contains comments on how this learning object is used.
    - The *language* represents the human language used by the typical intended user of this learning object.

- The *Rights* category groups the intellectual property rights and conditions of use for the learning object, e.g. costs, copyright restrictions, etc.
- The *Relation* category combines features that define the relationship between a particular learning object and other related learning objects.
- The *Annotation* category provides comments on the educational use of the learning object and provides information on when and by whom the comments were created.
- The *Classification* category describes the LO in relation to a particular classification system. The classification category may be used to provide certain types of extensions to the LOM version 1.0.

2.4.5 IMS Metadata Specification

2.4.5.1 IMS Learning Design

Organizations and educational consortiums have been putting great efforts on the development of the LOM metadata standard for effectively describing learning content. As a result, LOM has been widely accepted as the most advanced area in terms of standardization of learning technology. However, current needs in education indicate that learning should take more than the content into consideration. According to

Westera et al. (2005), learning is considered as an arrangement, which contains not only the learning content, but also a learning scenario, and learning tools & services. When learning occurs, in addition to learning content, learners also need to access certain learning tools and services, for example, calculators, software to edit text, or to send e-mail. Learning content, and learning tools and services should become part of learning activities, which comprise learner interactions with tutors, learners and learning resources. These learning activities and subsequent support activities are composed in so called learning scenarios that describe all interactions and transactions that occur in the learning environment, i.e. support events, exchanges of projects and communications between participants. Thus learning requires the availability of learning content, learning tools and services and learning scenarios (Figure 2-6).

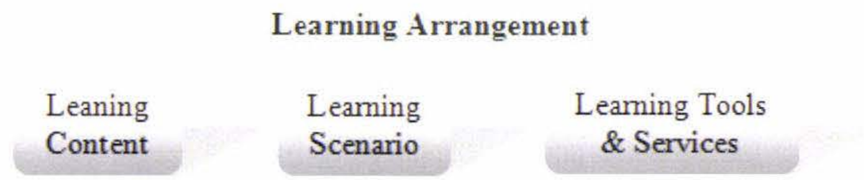

Figure 7 the Learning Arrangement (Westera et al., 2005)

Since LOM metadata only covers the description of learning content, it appears to be incompetent to handle statements about complex educational resources and interaction processes such as required learning services, tools, and learning scenarios. According to Van & Koper (2006), most specifications focus on the description of learning objects and metadata and on sequencing learning objects. Metadata specifications such as Dublin Core and IMS LOM are used to describe elements that are then used to assemble learning objects into 'courses', but they are too limited to describe the interaction between the elements. This has also been further proved by Steinacker (2001) that LOM does not provide any means to account for the method of instruction and it does not provide a vocabulary which is rich enough for describing contributor roles of persons engaged in educational activities. Fraunhofer IAO (2003) stated that "Using modular learning resources to build individual lessons automatically requires more information than the description of a single resource can provide". In order to cover a variety of pedagogical concepts, a broader framework is needed. For this purpose, IMS Global Learning Consortium established a new specification named IMS Learning Design (IMS LD) for online learning.

The objective of the IMS Learning Design specification is to provide a containment framework of elements that can describe any design of a teaching-learning process in a formal way (Caeiro et al., 2003). According to current research by Koper (2006), Koper & Olivia (2004), the IMS Learning Design is developed to meet following pedagogical and technical requirements.

- *Completeness*: The specification fully describes the teaching-learning process in a unit of learning, including references to the learning objects and services needed during the process.

- *Pedagogical expressiveness*: The specification provides the ability to support multiple pedagogical approaches through a single notation, and to describe learning designs based on all kinds of pedagogies. Thus designing biases towards any specific pedagogical approach are avoided.

- *Personalization*: The specification supports generic properties and conditions enabling dynamic personalization/adaptation, including accessibility, so that the content and activities within a unit of learning can be adapted based on the preferences, portfolio, pre-knowledge, educational needs and situational circumstances of users.

- *Compatibility*: By extending existing standard specifications, the Learning Design also inherits most of the general requirements for interoperability specifications and standards. Thus it can use and effectively integrate other available standards and specifications (e.g. LOM, IMS, etc.) where possible.

Rather than only focusing on learning content, the Learning Design metadata specification is defined by Koper & Olivier (2004) as an application of a pedagogical model for a specific learning objective, target group and a specific context or knowledge domain. The learning design specifies the teaching-learning process. To be more specific, the general concept of LD can be summarized as follows: A person gets a role in the teaching-learning process; this role can either be the role of a learner or staff. For a role, outcomes are stated as learning objectives, these outcomes are to be achieved by performing learning activities for learners, or support activities for those in a staff role. During the performance of activities, if learning objects or services are needed then these are placed in the environment embedded in the activity. Which role has to perform which activity and at what moment in the teaching-learning process is specified by the LD method either through conditions or by means of notifications (Koper & Olivier, 2004; Van & Koper, 2006). Figure 2-7 illustrates a semantic model that represents the learning design.

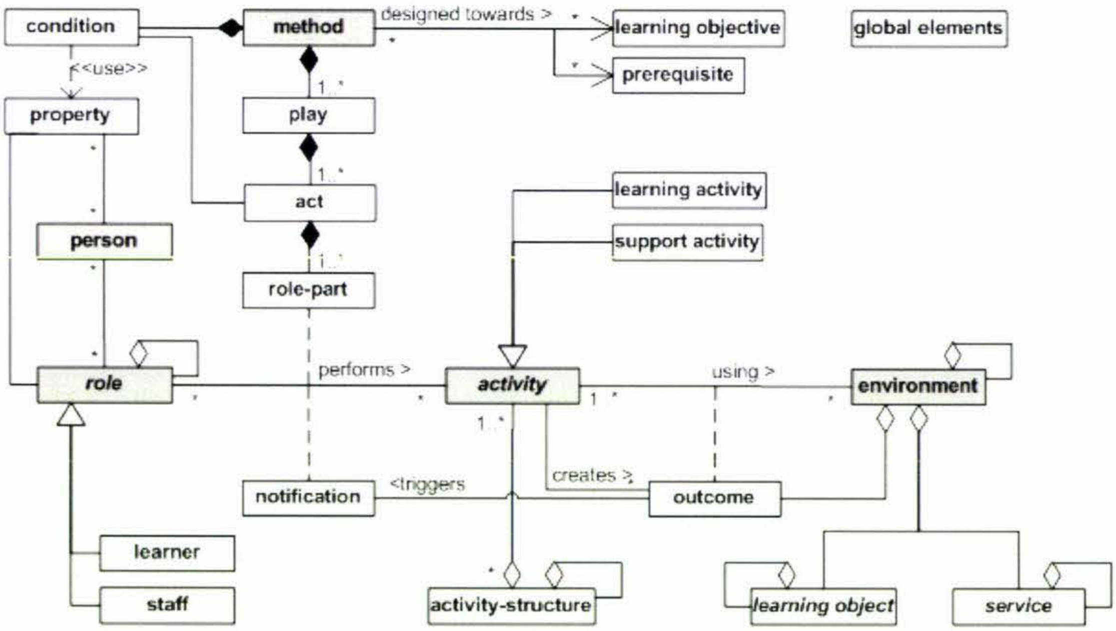

Figure 8 the Semantic Model for Learning Design (Koper & Olivier, 2004)

The IMS Learning Design specifies under which conditions, what activities have to be performed by intended user role to enable learners to attain their learning objectives. Amongst this process, the activities can refer to different learning objects that are used during the performance of these activities (e.g. books, articles, software programs, pictures), and it can refer to services (e.g. forums, chats, conferences) that are used to collaborate and to communicate in the teaching-learning process. Finally, all this information (including both pedagogical information and information needed to locate and use the required resources) that is needed during the learning process is encapsulated in one package to form a "unit of learning" (figure 2-8), which can be conveniently reused and shared among diverse communities. So far, IMS Learning Design is the only specification that covers the whole learning arrangement, because it not only allows the specification of learning scenarios, but it also supports existing technology specifications for learning content and learning tools and services (Westera et al., 2005).

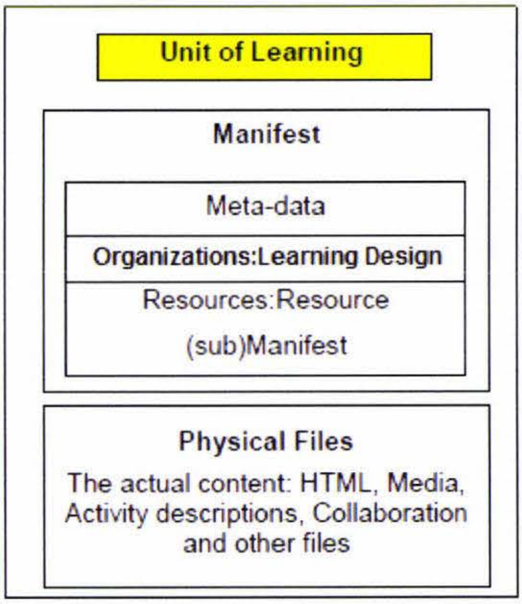

Figure 9 IMS Unit of Learning (Van & Koper, 2006)

2.4.5.2 IMS Learner Information Package

In common learning process, in addition to acquiring the learning content, services, tools and describing the learning scenario, making sense of information about individual learner is also critical. Learners exhibit diverse cognitive preferences, knowledge, competencies, interests, motivations, and learning goals in a specific learning process. To achieve the effective adaptivity in educational systems, it is essential and even inevitable that the learner information should be taken into consideration in the process of learning system development.

To describe and categorize information of the individual learner in a more reliable and standardized way, the IMS established another metadata specification named "Learner Information Package" (LIP). According to IMS (2001a), the Learner Information Package describes characteristics of a learner for the following general purposes:

- Recording and managing learning-related history, goals, and accomplishments;
- Engaging a learner in a learning experience; and
- Discovering learning opportunities for learners.

Basically, the LIP offers 11 categories to cover different aspect of a single learner's information. These categories were chosen to meet the requirements of a large variety of use cases and to facilitate mapping among IMS and other relevant specifications. Figure 2-9 illustrates the overall structure of the LIP.

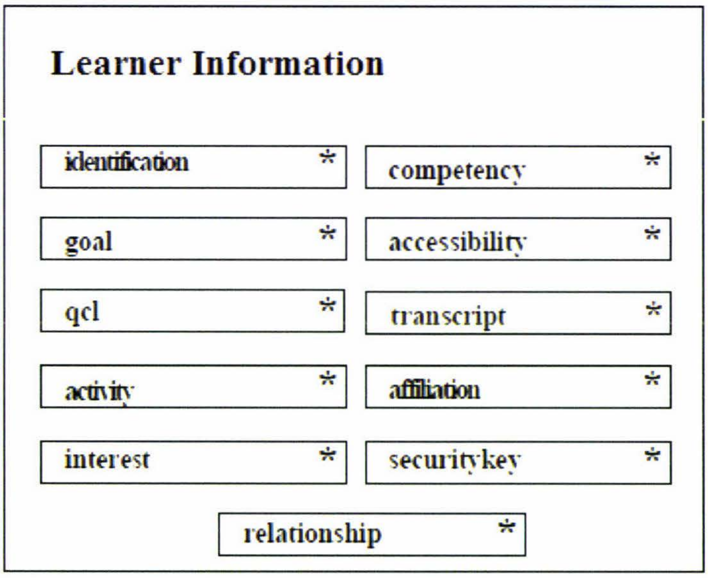

Figure 10 IMS Learner Information Package (IMS, 2001b)

- *Identification*: Biographic and demographic data relevant to learning.
- *Goal*: Learning, career and other objectives and aspirations.

- *Qualifications, Certifications and Licenses (qcl)*: Qualifications, certifications and licenses granted by recognized authorities.

- *Activity*: Any learning-related activity such as formal and informal education, training, work experience, and military or civic service.

- *Transcript*: A record that is used to provide an institutionally-based summary of academic achievement.

- *Competency*: Skills, knowledge, and abilities acquired in the cognitive, affective, and/or psychomotor domains.

- *Affiliation*: Membership of professional organizations, etc. Membership of groups is covered by the IMS Enterprise specification.

- *Accessibility*: General accessibility to the learner information as defined through language capabilities, disabilities, eligibilities and learning preferences including cognitive preferences (e.g. issues of learning style), physical preferences (e.g. a preference for large print), and technological preferences (e.g. a preference for a particular computer platform).

- *Security key*: The set of passwords and security keys assigned to the learner for transactions with learner information systems and services.

- *Relationship*: The set of relationships between the core components (IMS, 2001a).

2.5 Summary

In this chapter we addressed the importance of learning content selection within the scope of current educational system development, and especially investigated the close relationship between the content selection and adaptive intelligent educational systems. Not only does the adaptive learning content selection facilitate the traditional learning resources delivery process, it also provides the basis for various adaptation techniques in adaptive educational systems. Content selection is considered as the first step towards the adaptive navigation and adaptive course sequencing technique, and more importantly, it offers a concrete approach to realize the adaptive information filtering so as to narrow down the learning resource searching space. In addition, we investigated various pedagogical and technical factors that could influence the procedure of learning content selection. Especially, the learner profile (mainly focusing on learning style) and the domain knowledge (mainly focusing on learning theory) are considered to be the most critical contributions. Lastly, we introduced various standardized educational metadata specifications. The metadata standard is highly related with leaning content selection due to its interoperable, permanent, and accredited nature. Amongst the diverse specification, the IEEE LOM effectively facilitates the description, discovering, and interchange of learning content, while IMS Learning Design provides a comprehensive framework to address the complex learning/teaching scenarios. In addition, the IMS Learner Information Package offers reliable description and categorization for information of an individual learner. Combining these metadata specifications all together, a comprehensive framework for illustrating a complete learning procedure is available, and this availability can further facilitate the development of educational applications.

Chapter 3 Concept Design and Analysis

3.1 Introduction

In this chapter we first investigate issues of current approaches regarding learning content selection. Focus is mainly put on the examination of pedagogical theory support. Afterwards, based on the aspects discussed in the literature, we present the concept framework and methodology of our solution for learning content selection. The rest of the chapter provides comprehensive steps of the system's concept development details.

3.2 The Problem of Learning Content Selection

With the rapid evolution of the e-learning technology, adaptively and intelligently choosing suitable learning content to provide students with personalized learning experiences is becoming a prevailing trend in recent educational system developments. Adaptive learning content selection systems are built to offer the possibility of being a real alternative or support to the traditional face to face learning resources delivery processes. Aiming at this goal, a critical issue is raised in the development of such content selection systems, that is, how to provide an effective approach to mimic the human decision making process for retrieving suitable learning content, and at the same time, undertake that the selected content to most extent makes pedagogical sense.

3.2.1 Pedagogical Theory Support

Recently, practitioners have proposed various solutions in order to achieve the adaptivity in learning content selection. Primarily, the key efforts have been focused on setting up principles for content selection and instructional planning, because the selection of learning materials is based on these principles according to pedagogical theories (Stash et al., 2004; Brusilvosky et al., 2003). Nonetheless, most of these principles lack domain context, and there are no well-defined and widely accepted rules on how exactly the learning content should be selected (Knolmayer, 2003; Mohan et al., 2003). On the other hand, many content selection approaches did not seem to provide adequate references to current scientific principles of pedagogical theories or frameworks in the development of practical systems. This problem has already been addressed by earlier research, which emphasized that there is currently little evidence of how miscellaneous instructional theories are applied to effective pedagogically driven educational systems (Clegg et al., 2003; Lisewski et al., 2003; Oliver, 2002). In spite of the emergence of new technologies, this design weakness did not seem to be improved up to now. As recently mentioned by Ciaffaroni (2006), many practitioners still seemed either to be completely unaware that any learning environment refers implicitly or explicitly to a learning theory, and is based upon a pedagogical framework, or they did not teach what they preached as the saying goes. It is due to this ignorance that the radical adoption of technology still did not seem to provide evidently added value compared with traditional face to face teaching/learning approach in terms of the quality of learning consequences. One reason for the lack of pedagogical theory awareness for system designers might be that, they find the diverse array of theoretical perspectives overwhelming (McNaught, 2003). Another major reason might be that, explaining how learning takes place and analyzing the factors that have influence on it, remains somewhat confused, and besides, different psychological theories sometimes present contradictory explanations of learning towards each other (Brian, 1998). In spite of the facts stated above, most researchers agree that the significance of learning theory is not replaceable in the context of instructional design. We consider that as long as these conflicts are carefully handled, learning design still can be effectively and reliably guided by proven theories rather than based on the designer's instructional biases or the technical phenomenon.

As equally important as other influential factors (such as learner preference, learning domain, etc.), learning theories play crucial role in the design of adaptive educational systems, they offer empirically-based accounts of the variables which influence the learning process, and provide explanations of the ways in which that influence occurs (Calvani et al., 2006). By making learning theories more accessible, we can facilitate and support wider use of pedagogy in adaptive learning design, provide the development of educational tools with wealthy instructional guidelines, and improve the sharing of pedagogy within communities. The lack of pedagogical theory support in the development of educational system will be highly possible to cause weak instructional offering.

3.3 Concept Framework Design

3.3.1 Purpose and Framework Requirements

The purpose behind the proposed solution is to enhance the traditional human based learning content retrieving process by adaptively offering pedagogically sound recommendations for learning resources selection. To achieve this goal, the proposed solution results in the development of a multi-criterion based recommendation tool for learning content selection. By interacting with multiple criteria, learners can obtain guidelines for selecting content that best suit their needs. As discussed in the section 3.2, many content delivering approaches are facing the problem of lack of effective support of authoritative pedagogical theories, which causes the weak instructional offering. To solve this issue, the proposed framework expects to establish a "unit of learning content" selection model with multiple instructional criteria and dependency matching rules embedded by taking advantages of classic psychological theories and educational metadata standards. For this purpose, the framework is expected to meet following fundamental requirements:

- *Target user* – The *target users* of this tool are intended to be the students from different learning disciplines, and from various physical locations, while the final generated recommendations could be used both by students (searching for content) and by teachers/course designers (searching content and design learning activities).

- *Correlated Parameters* – The proposed system is expected to provide intelligible and dynamically interdependent parameters, so as to deliver a negotiating environment for the users to select suitable learning content in a negotiable manner.

- *Dependency matching rules* – as the core element of this framework, the working model is expected to offer sound pedagogical principles on how content, services, and activity guidelines are inter-related with specific student within various learning domains. In addition, to undertake the quality outcome, the embedded matching rules need to base on classic instructional theories.

- *Standards adoption* – the criteria identified for describing the unit of a learning content are expected to conform to the corresponding elements in educational metadata standards, so as to guarantee the credibility and interoperability.

- *Multi-discipline support* – To ensure a broad range of application, the proposed framework is expected to offer *multi-discipline* (learning domain) support instead of the proprietarily focusing on specific learning subject.

The proposed content selection framework is illustrated as figure 10.

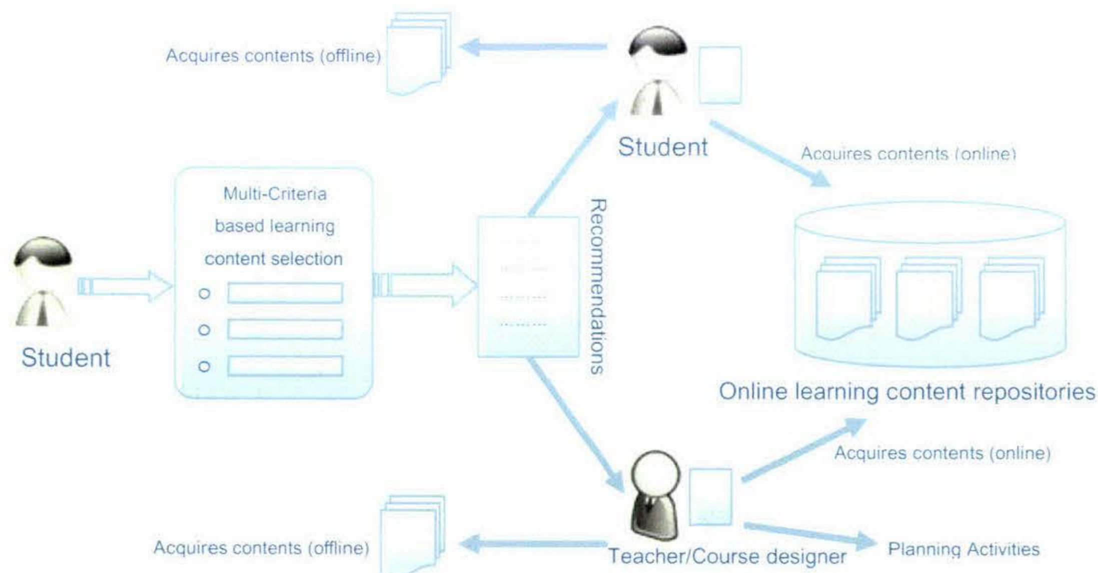

Figure 11 Framework for multi-criteria based learning content selection

3.3.2 Parameters Identification

We consider that any single learning content exhibits unique attributes of its own, which are usually described in a set of parameters. Different parameters represent different aspects of the content's characteristics. It is self-evident that the process of content selection is actually about confirming the particular value of each parameter describing the learning content. However, in the real application context, the selection of learning content is by no means as simple as just grabbing a value from its corresponding parameter. First of all, it involves the identification of appropriate parameters that are capable for describing the content. Secondly, it is inevitable that many parameters are actually interrelated with each other. In many cases, the value of a parameter depends on how values of other particular parameters are changed. Especially in the context of this research, relations among various parameters are rather complex due to the strong pedagogical characteristics of these parameters.

3.3.2.1 Investigation of Standardized Metadata Elements

Identifying appropriate parameters for describing characteristics of content is the most essential step for learning content selection. Nevertheless, how to guarantee the introduced parameters have the most accreditation remains challenging. In the earlier approaches, the identification of criteria lied on system designers' own understanding of the pedagogy. However, this causes a problem that the credibility of identified criteria is hard to certify.

To overcome this shortcoming, this research proposes a solution by turning relevant elements in various educational metadata standards into resource selection parameters in the form of an application profile. As investigated in the literature review, educational metadata standards provide a standardized framework to describe almost every aspect of the learning processes, such as the learning material, learner profile, learning scenario, activity, supporting service, and so on. Most importantly, the adoption of this converting approach is mainly due to the accredited nature of the metadata standards. The educational metadata standards are produced by 'accredited' organizations. It is highly authoritative, and guarantees an open, fair, transparent and inclusive process compared to those so called 'de facto' standards that are based on specifications made by individuals, groups, or companies.

Therefore, the identification of suitable criteria for the proposed selection framework involves a full-scale investigation of various educational metadata specifications, which include IEEE LOM, IMS Learning Design, and IMS Learner Information Package. By this means, appropriate metadata elements that are considered to be contributive to the proposed content selection concept will be adopted according to their pedagogical relevance to the factors that influence the process of learning content selection.

3.3.2.2 Refinement of Parameters

The proposed system emphasizes on the adoption of psychological theories based on a pedagogical perspective. Hence the identification of criteria in this research is primarily focused on the discovery of metadata elements that are strongly relevant to the pedagogical and psychological attributes of the general learning process.

In the literature review chapter, we have discussed that learner's profile, knowledge about the domain, and characteristics of content offer the most pedagogical hints for supporting instructional decision making on learning content selection. Therefore, by taking these pedagogical clues into account, thirteen elements were eventually identified as the "pedagogically capable" criteria for the content selection framework. The proposed parameters and their corresponding elements are depicted in table 1:

Table 1 the Parameter/Element Mapping Details

Parameter	Metadata Element
Learning Domain	lom/classification/purpose[discipline] (LOM)
Learning Theory	learning-design/component/activities (IMS LD)
Learning Style	accessibility/Preference (IMS LIP)

Service Facility	learning-design/component/environment/service (IMS LD)
Role-Part	learning-design/component/roles (IMS LD)
Timing Control	learning-design/method/play/complete-activity (IMS LD)
Learning Resource Type	lom/educational/learning resource type (LOM)
Definition/Examples	Examples for "learning resource type" element (SCORM)
Interactivity type	lom/educational/interactivity type (LOM)
Aggregation Level	lom/technical/aggregation level (LOM)
Structure	lom/technical/structure (LOM)
Interactivity Level	lom/educational/interactivity level (LOM)
Semantic Density	lom/educational/semantic density (LOM)

- ***Learning Domain***

The learning domain here is mainly referred to as the educational discipline in which the learner is studying. It could be similarly comprehended as the word "subject", but its range is slightly wider than that. It mainly addresses learning from the perspective of human skills. The learning domain (discipline) is an important factor that affects content selection. For instance some disciplines require strong practical exercises while some others emphasize more on literature study. At this stage, we have identified 12 values (*aviation, computer, decision making, engineering, language, management, mathematics, medicine, military, sales, sensory-motor,* and *troubleshooting*) covering different learning domains for this parameter.

- ***Learning Theory***

The learning theory here is referred to as classical human psychological theories for education. As discussed in the literature review, the learning theory is capable of describing how learning activities proceed, and offers knowledge association between instructional models and the learning design, so as to achieve the reliability of instructional prediction. The "activity" element from IMD LD is used for describing and planning instructional activities. It provides the identical purpose as the learning theory does. Therefore this element is chosen as the parameter to provide pedagogical guidelines for learning activity planning. In this research, we have identified about 50 classical learning theories (e.g. Adult Learning Theory, Experiential Learning, Social Learning Theory, and so on) for the proposed *Learning Theory* criteria.

- ***Learning Style***

The IMS LIP (2001) provides the "preference" element to describe individual learner's cognitive preferences or learning styles. The learning style addresses the key aspect of learner's information. Different learning content or learning activities are particularly favored by the learners with different learning styles. By adopting the learning style theory, particular learning resources can be intentionally matched with the suitable learners, so as to achieve more effective learning experience and better learning outcomes. According to the investigations in the literature review, the Honey & Mumford learning style theory is proposed to be used for this parameter, and its four types of learners (*activists, reflectors, theorists,* and *pragmatists*) are converted into the parameter values.

- ***Service Facility***

As discussed previously, learning is considered as an arrangement. Supporting services and tools are one of the core components needed for performing or facilitating the process of learning. According the vocabularies definition of this element suggested by IMS LD (2003) specification, *Collaboration Services* (e.g. conference system, whiteboard tools, wikis), *Communication Services* (e.g. email services, instant message tools), and *Search Services* (e.g. search engine, library indices) are included as the recommended values. Therefore values of the proposed *Service Facility* parameter are derived from these vocabularies.

- ***Role-Part***

In learning processes, how/what people are involved to the leaning activities is also an important issue. For instance, some learners prefer completely self-guided learning rather than following a mentor's coaching, because they find working alone raises less pressure than studying under the teacher's rules and vice versa. According to IMS ID (2003), the "role" element provides two vocabularies ("*learner*" and "*staff & learner*") to identify the situation where people should participate in a particular learning process. Therefore, the values of the Role-Part parameter derive these two vocabularies.

- ***Timing Control***

For the similar reason described above, there would be a choice of whether the duration of learning process is controlled by the learners themselves or is limited in a specific period of time by instructors or by the learning content itself. Based on the vocabulary definition in IMS LD (2003), this parameter has two values (*user-choice* and *time limit*) deriving from the "complete-activity" element.

- ***Learning Resource Type***

The Learning Resource Type parameter here represents the various kinds of learning objects that can be used to form the content. The IEEE LOM specification uses "learning resource type" element to provide definitions of different types of learning objects. According to IEEE LOM (2002), the learning objects are broken into ten categories (*Exercise, Simulation, Questionnaire, Figure, Index, Table, Narrative Text, Exam, Problem Statement,* and *Lecture*). Accordingly, this parameter uses those defined vocabularies as values to address the characteristics of different kinds of learning objects. Although LOM specification does not provide the exact definitions for these types, according to OED (2000)'s explanation, we can still present the definitions for each learning resource type as follows:

- Exercise- the use of or method of using; a task prescribed or performed for the sake of attaining proficiency, for training either body or mind, or as an exhibition or test of proficiency or skill
- Simulation- the technique of imitating the behavior of some situation or process (whether economic, military, mechanical, etc.) by means of a suitably analogous situation or apparatus

- Questionnaire- a list of questions by which information is sought from a selected group, usually for statistical analysis
- Figure- the image, likeness, or representation of something material or immaterial
- Index- a reference list; an alphabetical list
- Table- an arrangement in columns and lines...as the multiplication table, tables of weights and measures, a table of logarithms, astronomical tables, insurance tables, time-tables, etc.
- Narrative Text- an account or narration; a history, tale, story, recital (of facts, etc.) that is a portion of the contents of a manuscript or printed book, or of a page, which constitutes the original matter, as distinct from the notes or other critical appendages
- Exam- the process of testing, by questions oral or written, the knowledge or ability of pupils, or of candidates for office, degrees, etc.
- Problem Statement- a written or oral communication setting forth; a difficult or puzzling question proposed for solution
- Lecture- a discourse given before an audience upon a given subject, usually for the purpose of instruction

- ***Definition/Example***

Specially, we intend to use this parameter to give learners a general hint to indicate to which learning resource type exactly a learning object belongs to, so that a learner can have a better understanding on what actual learning object they might select for a recommended learning resource type. For example, if the "narrative text" is chosen as the intended learning resource type, then the learning resources such as the lecture, literature, story, research study, and so on, could be considered as potential learning object candidates. In addition, this parameter is derived neither from LOM nor from

Learning Design, but is specially inherited from SCORM[1], which offers an extension (appendix A) to the "learning resource type" element by providing examples.

- ***Interactivity Type***

When a learner is searching for a learning object, it is necessary to specify how the learner can interact with the required learning object. For this purpose, the LOM specification introduces the "interactivity type" element. IEEE LOM (2002) recommends three vocabularies for this element. They are *active, expositive*, and *mixed*. According to IEEE LOM (2002), the vocabulary "active" can be considered as learning by doing, which means learning is supported by content that directly induces productive action by the learner. An active learning object prompts the learner for semantically meaningful input or for some other kind of productive action or decision; the "expositive" can be referred to as the passive learning, which means learning occurs when the learner's job mainly consists of absorbing the content exposed to him. An expositive learning object displays information but does not prompt the learner for any semantically meaningful input; finally if a learning object blends the *active* and *expositive* interactivity types, then its interactivity type is "mixed". Accordingly, this proposed parameter uses the vocabularies above as values.

- ***Semantic Density***

In the content selection process, users also concern about the intensity of information presented within a specific learning object. For instance, a page containing large amount of descriptive text may only offer little knowledge for a specific learning topic. On the contrary, a one line symbolic formula can sometimes represent huge amount of theoretical information. Therefore, IEEE LOM uses "semantic density" element to achieve this intensity measurement. According to IEEE LOM (2002), five vocabularies (*very low, low, medium, high,* and *very high*) are defined for this element.

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[1] SCORM: stands for Sharable Content Object Reference Model supported by US Department of Defense. It provides a metadata model describing learning content from its most basic form with the conformance to IEEE LOM standard.

These vocabularies are also turned into values for the "Semantic Density" parameters in the proposed system.

- ***Interactivity Level***

In addition to specify the type of interactivity of a learning object, to what extent a learner can interact with the desired learning object also needs to be considered in content selection. IEEE LOM (2002) defines the "Interactivity Level" as the degree to which the learner can influence the aspect or behavior of the learning object and similarly offers five vocabularies ("*very low*" to "*very high*") to measure this degree. The proposed "Interactivity Level" parameter also inherits these values.

- ***Aggregation Level***

The aggregation level is also known as the granularity of a digital learning resource (Wagner, 2002). IEEE LOM defines this element as the functional granularity of a learning object (IEEE LOM, 2002). It indicates the degree to which learning resource or the parts of the resource can be decomposed into smaller components. Although this element describes managerial aspect of content's characteristics, it still can in a way provide hints on describing the content's scale or organization. Therefore the proposed "Aggregation Level" parameter inherits the values ("level 1" to "level 4") from this element. According IEEE LOM (2002), the four levels are described as follows:

1. The smallest level of aggregation, e.g. raw media data or fragments.
2. A collection of level 1 learning objects, e.g. a lesson.
3. A collection of level 2 learning objects, e.g. a course.
4. The largest level of granularity, e.g. a set of courses that lead to a certificate.

- ***Structure***

According to IEEE LOM (2002), the "Structure" indicates the way in which the learning resource is logically related to other resources to form a composite resource. In the actual content selection process, the underlying organizational structure of the learning objects would also be of interest to users. It provides a basic idea about how desired objects are organized. As defined by IEEE LOM, a learning object can have five different structures (*atomic, collection, networked hierarchical,* and *linear*). They are all converted into values for the proposed "Structure" parameter. The detailed descriptions of these structures are listed below.

- *Atomic* - Any resource that is a raw media file or fragment.
- *Collection* - Any set of resources with no established relationships or defined links between them.
- *Networked* - Any set of resources that are interrelated in a manner that is neither clearly hierarchical nor linear, or where relationships exist but are not clearly or consistently specified.
- *Hierarchical* - Any set of resources that are interrelated with a logical tree structure.
- *Linear* - Any set of resources that are interrelated as a single sequence.

3.3.4 Parameter Dependencies Mapping

As investigated in this research, parameters for content selection are not isolated entities. Considering the real learning environment, the parameters exhibit certain strong interrelationship or dependencies between each other. Especially, these interrelationships are even more evident on those criteria that cover pedagogical characteristics of learning resources. A change of the value on a certain criteria may cause changes of the availabilities or values of other criteria. For example, in the case of our proposed framework, if a user's learning style is changed, the supporting services, suitable learning objects, and even the way he/she controls the learning might accordingly vary based on the particular value of that person's learning style. Therefore, if these correlations and dependencies are correctly addressed and handled, every time when users are accessing the attributes of the content, appropriate options of parameter values can be dynamically prompted to the users in a most relevant range, and values that are irrelevant to current criteria context can be effectively excluded. Thus the resulting recommendations can significantly reduce the content searching space and at the same time, improve the instructional logics of the selected content, so as to make the pre-selected learning content more pedagogically meaningful.

Based on the discussion above, the identification and mapping of proper dependencies between the proposed parameters is the key task for this research. Although metadata standards offer reliable and accredited criteria to address attributes of learning resources, they do not present any explicit elaboration on how the criteria are associated with each other. As discussed in the literature chapter, proven pedagogical theories are capable to provide instructional hints for identifying information about the associations between instructional module and the learning process, and supply implications on how specific teaching/learning strategies or resources best suit target educational circumstances and specific learners. For this reason, we establish the dependency rules by taking advantages of existing pedagogical theories.

3.3.4.1 Mapping Learning Domain Related Parameters

Effective learning is said to be achieved through the engagement with ordinary practices of the subject domain or culture (Brown et al. 1989). In the real learning situation, it is not hard to identify that learning subjects (learning domains) are particularly relevant to learning resources and learning activities. Different learning subjects focus on the development of different specific skills and domain knowledge of a learner. To achieve better effectiveness, resources and activities that are especially advantageous to this development should be contextualized to the target learning domain. This point is also supported by Jones (2004) that, by making a learning resource context free, the learner is not given the opportunity to relate the subject of that resource to the particular subject area they are studying and with which they feel familiar.

Therefore, in our proposed framework, we establish the learning domain related dependencies rules by mapping learning domain with learning resource type and learning theory parameter based on proven pedagogical theories recapitulated by

Kearsley (2006)'s Theory into Practice Database[2]. Table 2 gives the mapping details for learning domain and learning resource type parameters.

Table 2 the Dependency Mapping for Learning Domain and Learning Resource Type

Learning Domain	Characteristics of the Domain (Kearsley, 2006)	Preferred Learning Resource Type	Literature
Aviation	• visual processing skill is critical; • Simulators are an important component; three major categories of skills: • Procedure; • Decision-making; • Perception;	Simulation Figure	Gibson (1979) Caro (1988)
Computers	• problem-solving and procedures are the major cognitive processes; • Involves troubleshooting activities; • Simulation games help children learn; • Experience and Self-direction are important	Simulation Problem Statement Figure Exam	Card et al. (1983) Heerman (1986) Zemke (1984)
Decision Making	• memory, reasoning, and concept formation play a primary role; • closely associated with study of attitudes, creativity, and problem-solving; • involve stages such as recognition, formulation, generation of alternatives, information search, selection, and action;	Questionnaire Figure Problem Statement	Hammond et al. (1980) Kaplan et al. (1975) Simon (1976) Janis et al. (1977)
Engineering	• problem-solving and reasoning are critical cognitive process; • Frequently involve mathematics, innovations; • Team work; • self-directed and experiential learning; • Communication skills for future needs;	Simulation Problem Statement Exam Figure	Denning (1992) Kemper (1982)
Language	• primary factors including association, reinforcement, and imitation; • Correction of errors helps to understand the grammar; • Listening, speaking, reading, and writing processes • Interaction with others is critical; • Understanding & communication; • Conscious monitoring of language use	Simulation Narrative Text Lecture Exercise	Brown (1980) Krashen (1981) Clark et al. (1977)

[2] The Theory into Practice Database: Kearsley's research database containing brief summaries of 50 major theories of learning and instruction which can be accessed by learning domains and concepts.

Management	• Specific skills including negotiation, budgeting, communication, planning, leadership, handling stress; • Learning takes place through interacting with others; • modeling and role playing • Building learner experience is important; • Structured projects in organizations rather than traditional classroom instruction; • Problem-solving is a critical skill; • Coaching and mentoring are often used;	Simulation Lecture Problem Statement	Roth (1985) Deegan (1979) Kolb (1984) Revans (1980)
Mathematics	• Four critical skills: resources, heuristics, control processes, and beliefs; • Acquisition of higher-order rules is the fundamental aspect	Problem Statement Figure	Schoenfeld (1985) Ellis (1938) Scandura et al. (1980)
Medicine	• Knowledge is immense and constantly changing; • Memory process is highly critical; • Emphasizes decision-making, reasoning, and problem-solving skill; • Self-directed learning activities • Experiential learning are highly pertinent	Exercise Simulation Problem Statement Narrative Text	Barrows et al. (1980) Norman et al. (1992)
Military	• Extensive interpersonal interaction, team work are involved; • Decision-making, problem solving, and memory are the fundamental skills; • Simulators are widely applied	Simulation Problem Statement	Modrick (1986) Ellis (1986)
Sales	• Experience and self-direction are particularly relevant; • Role-playing, simulations, and apprenticeship are frequently used; • Social interaction • Involve decision-making and problem-solving skills	Lecture Simulation Problem Statement	Russell et al. (1982)
Sensory-Motor	• Various practices are highly crucial; • Needs prompting and guidance; • Feedbacks in correcting motor behavior are important; • Mental rehearsals facilitate performance	Simulation Figure Exercise	Singer (1975) Marteniuk (1976)
Troubleshooting	• Involve two stage: hypothesis generation and hypothesis evaluation; • Meta-cognition plays an important role • Guidance for problem-solving improve performance; • Task-related knowledge are important;	Simulation Figure Exam	Morris et al. (1985)

Table 3 illustrates the dependency mapping details for Learning Domain and Learning Theory parameters.

Table 3 the Dependency Mapping for Learning Domain and Learning Theory Parameters

Learning Domains	Suitable Learning Theories (Kearsley, 2006)	Literature
Aviation	Information Pickup Theory Conditions of Learning Criterion Referenced Instruction Structure of Intellect Multiple Intelligences	Gibson (1966) Gagne, (1985) Mager, (1975) Guilford et al. (1971) Gardner (1993a)
Computers	GOMS Minimalism Adult Learning Theory Conversation Theory Symbol Systems Cognitive Flexibility Theory	Card et al. (1983) Carroll (1998) Cross (1981) Pask (1975) Salomon (1979) Spiro et al. (1992)
Decision Making	Experiential Learning Andragogy Adult Learning Theory Double Loop Learning	Rogers (1969) Knowles (1984) Cross, (1981) Argyris (1976)
Engineering	Social Learning Theory Social Development Adult Learning Theory Andragogy Experiential Learning Criterion Referenced Instruction Symbol Systems	Bandura (1977) Vygotsky (1978) Cross (1981) Knowles (1984) Rogers (1969) Mager (1975) Salomon (1979)
Language	Adult Learning Theory Andragogy Experiential Learning Functional Context Theory Constructivist Theory Genetic Epistemology Drive Reduction Theory Operant Conditioning Connectionism Subsumption Theory Algo-Heuristic Theory Script Theory ACT* Levels of Processing Dual Coding Theory Social Development Multiple Intelligences Structure of Intellect Triarchic Theory	Cross (1981) Knowles (1984) Rogers (1969) Sticht (1976) Bruner (1960; 1966) Piaget (1969) Hull (1940; 1943) Skinner (1957) Thorndike (1913) Ausubel (1963) Landa (1975) Schank et al. (1977) Anderson (1983) Craik et al. (1972) Paivio et al. (1991) Vygotsky (1978) Gardner (1993a) Guilford et al. (1971) Sternberg (1977)
Management	Double Loop Learning Social Learning Theory Adult Learning Theory Andragogy	Argyris (1976) Bandura (1977) Cross (1981) Knowles (1984)

	Experiential Learning	Rogers (1969)
	Lateral Thinking	DeBono (1967)
Mathematics	ACT*	Anderson (1983)
	Repair Theory	Brown (1980)
	Conversation Theory	Pask (1975)
	Gestalt Theory	Wertheimer (1923)
	Mathematical Problem Solving	Schoenfeld (1985)
	Structural Learning Theory	Scandura (1977)
	Constructivist Theory	Bruner (1960; 1966)
	Algo-Heuristic Theory	Landa (1975)
	Multiple Intelligences	Gardner (1993a)
	Structure of Intellect	Guilford (1971)
Medicine	ACT*	Anderson (1983)
	Dual Coding Theory	Paivio (1991)
	Levels of Processing	Craik et al. (1972)
	Cognitive Flexibility Theory	Spiro et al. (1992)
	Adult Learning Theory	Cross (1981)
	Andragogy	Knowles (1984)
	Experiential Learning	Rogers (1969)
	Criterion Referenced Instruction	Mager (1975)
	Symbol Systems	Salomon (1979)
Military	Adult Learning Theory	Cross (1981)
	Andragogy	Knowles (1984)
	Experiential Learning	Rogers (1969)
	Social Learning Theory	Bandura (1977)
	Social Development	Vygotsky (1978)
	Structure of Intellect	Guilford et al. (1971)
	Multiple Intelligences	Gardner (1993a)
	Triarchic Theory	Sternberg (1977)
	Conditions of Learning	Gagne (1985)
	Component Display Theory	Merrill (1983)
	Elaboration Theory	Reigeluth (1992)
	Criterion Referenced Instruction	Mager (1975)
	Functional Context Theory	Sticht (1976)
Sales	Adult Learning Theory	Cross (1981)
	Andragogy	Knowles (1984)
	Experiential Learning	Rogers (1969)
	Social Learning Theory	Bandura (1977)
	Social Development	Vygotsky (1978)
Sensory-Motor	Contiguity Theory	Guthrie (1930)
	Drive Reduction Theory	Hull (1940; 1943)
	Operant Conditioning	Skinner (1957)
	GOMS	Card et al. (1983)
	Social Learning Theory	Bandura (1977)
	Social Development	Vygotsky (1978)
	Structure of Intellect	Guilford et al. (1971)
	Multiple Intelligences	Gardner (1993a)
Troubleshooting	Gestalt Theory	Wertheimer (1923)
	Information Pickup Theory	Gibson (1966)
	ACT*	Anderson (1983)
	Repair Theory	Brown et al. (1980)
	Soar	Newell (1990)
	Structural Learning Theory	Scandura (1977)
	Structure of Intellect	Guilford et al. (1971)

Triarchic Theory	Sternberg (1977)
Criterion Referenced Instruction	Mager (1975)

3.3.4.2 Mapping Learning Style Related Parameters

Based on the investigations on Honey & Mumford's learning style theory, we found that in learning situations, the changing of the learning style mainly causes variations on learner's habitual learning patterns. These variations eventually lead to diverse learning preference demands, which mainly cover the resource and environment aspect of learning, such as preferred supporting tools, time constraint, communication/collaboration environment, learning activities and its associated learning resources. Therefore, in the context of our proposed parameters, the criteria such as *Services Facility*, *Role-Part*, *Timing Control*, and *Learning Resource Type* are particularly relevant to individual learner's learning style. According to Honey & Mumford's (Honey et al., 1986; 1992) descriptions about learner's preferences regarding four types of learning styles, we build the dependency rules for learning style related parameters. These rules are summarized in table 4.

Table 4 the Dependency Mapping for Learning Style Related Parameters

Learning Style	Preference Descriptions Summary	Services	Role-Part	Timing Control	Learning Resource Type
Activists	• Simulations games, teamwork, role-plays; • Unstructured discussions, brainstorming; • Tackling a range of diverse activities; • Working under time, resources constraint; • Project; • Creative learning situations • Short Q & As - instant feedback • Problem-based learning; • Extrovert activities such as giving presentations, lead discussion, chair meetings.	Collaboration Services Communication Services	Learner Learner & Staff	Time Limit	Simulation Questionnaire Problem Statement
Reflectors	• Passive observing e.g. watching video, reading literature; watch	Collaboration Services Search Services	Learner	User Choice	Figure Narrative Text

	brainstorming event; • Well briefing before participating activity; • Hate time constraints; • Painstaking research; • Lack of pressure or deadlines for decisions; • Structured learning experience.				Lecture Exercise
Theorists	• Learning in a conceptual framework e.g. theory, concept, model; • Structured situations with a clear purpose; • Listening to, or reading about, well-argued, logic; • Research on background theory • Being intellectually stretched, i.e. analyze complex situations; • Interesting ideas even if they are not immediately relevant; • Understanding and participating in highly complex situations; • Questioning and probing assumptions and logic, e.g. Q & As, checking paper for inconsistencies	Search Services	Learner	User Choice Time Limit	Questionnaire Narrative Text Lecture Problem Statement Exercise Figure Table Index
Pragmatists	• Obvious links between theory and job practice; • Skills and techniques with obvious practical advantages e.g. how to manage time schedule; • Working with a credible expert; • Watching practical Demonstrations, simulations, films; • Working with real problems simulations, realistic case studies; • Given immediate and evident application; • Concentrating on practical Drawing up action plans.	Collaboration Services Communication Services	Learner Learner & Staff	User Choice Time Limit	Simulation Problem Statement Exercise

3.3.4.3 Mapping LOM Exclusive Parameters

Excluding the parameters being mapped above, the dependencies among the five parameters that are derived from IEEE LOM specification remain unidentified, because currently, it is not clear that, whether there is any empirical research capable to pedagogically depicting the correlations among these criteria. However, instead of searching for supporting pedagogical theories, some analytical approaches could be used as the alternative for exploring the criteria dependencies of these criteria. Najjar et al. (2003) provided an empirical analysis to present the actual use that is made of LOM metadata in ARIADNE Knowledge Pool System (learning object repository) by evaluating 3,700 metadata instances for learning objects from different science types, languages, contexts and granularities. According to the analytical results, a highly positive, statistical significant correlation is present between *Interactivity Level* and *Semantic Density* element, which means the value variation of these two elements is coherent and in the same direction; a moderately negative correlation is present between *Aggregation Level* and *Interactivity Level* element, which means the value variation of these two elements is in the opposite direction. For instance, if the value of *Semantic Density* is "high" then *Interactivity Level* will be most probably "high" too; if the value for *Aggregation Level* is "3" then we may suggest "Low" or "Medium" as value for *Interactivity level*. Furthermore, IEEE LOM (2002) specification also provides a dependency hint for the *Aggregation Level* and *Structure* element that, a learning object with the "Aggregation Level" equals to 1 will typically have the "Structure" equals to "atomic". A learning object with "Aggregation Level" equals to 2, 3 or 4, will typically have "Structure" equals to "collection", "linear", "hierarchical" or "networked".

To make these dependencies more recognizable, table 5 gives the dependency details for *Interactivity Level* and *Semantic Density* parameters; table 6 presents the dependency details for *Aggregation Level* and *Interactivity level* parameters; and table 7 provides the dependency details for *Aggregation Level* and *Structure* parameters.

Table 5 the Dependency between Interactivity Level and Semantic Density

Interactivity Level	Semantic Density
Very Low	• Very Low • Low
Low	• Low • Medium
Medium	• Medium
High	• Medium • High
Very High	• High • Very High

Table 6 the Dependency between Aggregation Level and Interactivity level

Aggregation Level	Interactivity Level
Level 4	• Very Low • Low
Level 3	• Low • Medium
Level 2	• Medium • High
Level 1	• High • Very High

Table 7 the Dependency between Aggregation Level and Structure

Aggregation Level	Structure
Level 4	• Linear • Hierarchical • Collection • Networked
Level 3	• Linear • Collection • Networked • hierarchical
Level 2	• Collection • Networked • Linear • hierarchical
Level 1	• Atomic

3.3.5 Finalizing Relationship Structure

Based on the current instructional literature and analytical research, we have identified the possible pedagogical correlations among criteria for the proposed content selection framework. Change of values on certain parameters will result the variations of other criteria's values. According to the results of the dependency mapping, the Learning Domain and Learning Style are the most influential parameters among the proposed criteria. Based on the variation of the *Learning Domain* parameter, the *Learning theory* and *Learning Resource Type* will be accordingly changed by following the dependency rules. Similarly, if the value of the *Learning Style* parameter is changed, the *Timing Control, Role-Part, Service Facility*, and *Learning Resource Type* parameter will accordingly adjust their values to fulfill the dependency context. Moreover, the values of Aggregation Level and Semantic Density will dynamically depend on how the Interactivity Level changes. Finally, the value of Aggregation Level determines how the Structure parameter presents its possible value. Figure 11 provides an overall structure to illustrate these correlation inter-dependencies.

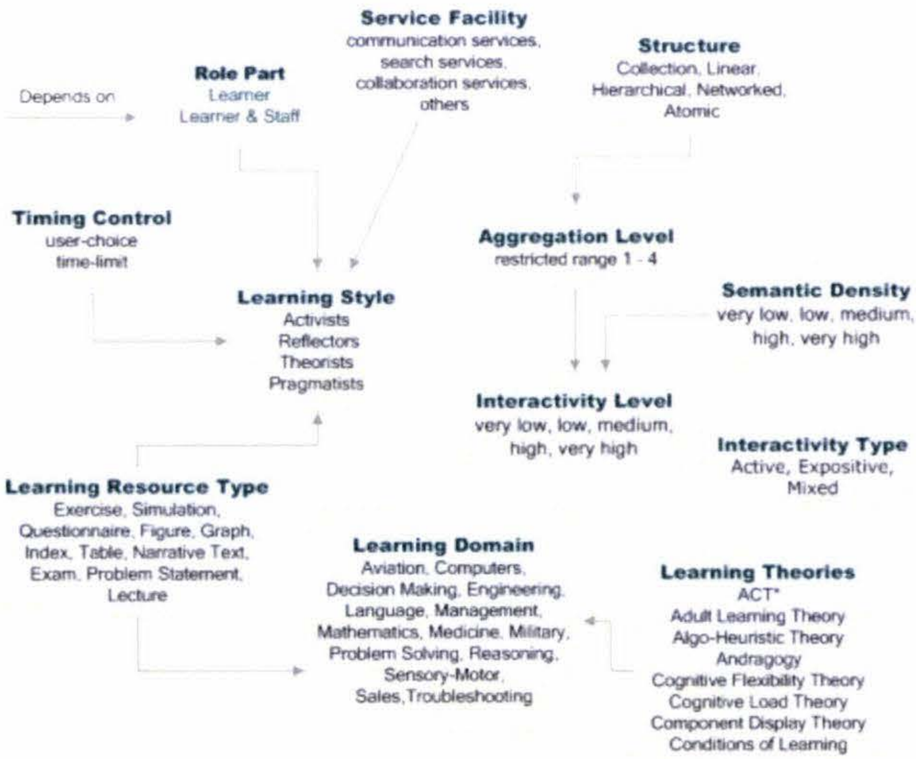

Figure 12 the Overall Criteria Dependencies

As demonstrated in figure 11, available values of the Learning Resource Type actually lie on two distinct criteria – the Learning Domain and the Learning Style. It is fair and reasonable that the suitable learning resources for a learner both rest with his/her preferred learning style and the domain in which he/she is studying. However, these two criteria dependencies might raise conflict, because disparate learning resource type recommendations might be offered by these two distinct parameters. To handle this dependency contradiction, we take the union of the two resource recommendation sets that are based on the Learning Domain and the Learning Style parameter as the final values for the Learning Resource Type parameter. Therefore, the system leaves the choice to the learner on whether he/she prefers the resources that are more relevant to the learning style or more relevant to the target learning domain. Thus, the system ensures that no relevant learning resource types are neglected for the learner.

3.4 Summary

In this chapter, we addressed the current issues about adaptive learning content selection. The main problem of content selection approaches is the lack of adequate references to current scientific principles of pedagogical theories or frameworks in the development of practical system. This usually causes pedagogically unreliable learning content delivery and leads to weak instructional offering. To overcome this problem, we choose to build the content selection system by strictly adhering to pedagogical theories and educational metadata standards, because classic theories provide empirically-based accounts of the variables which influence the learning process and offer wealthy instructional guidelines for the development of educational system; educational metadata standards complementarily supply highly accredited and authoritative descriptions for these instructional variables in a standardized way.

By keeping the above considerations in mind, we proposed a content selection framework, which is embedded with multiple instructional criteria and dependency matching rules. In the first step of the framework building process, we identified thirteen instructional parameters to form the criteria basis for the proposed selection model based on a full-scale elements investigation within various educational metadata specifications. Due to the strong pedagogical characteristics of the proposed criteria, existence of considerable correlations is found among these criteria. Through the intensive references to the current educational theories and analytical literature, we identified nine criteria dependency rules to address the interrelationship between these parameters. As a consequence, every time when a selecting action is performed, appropriate options of parameter values are dynamically prompted to the learner to meet the dependency context in a most relevant range, so as to provide a negotiable selection environment for the learner to effectively reduce the content searching space.

Chapter 4 System Design and Implementation

4.1 Introduction

In this chapter, we present an elaboration of the system implementation details. Firstly, the system functionalities and its overall working process are outlined, followed by the illustration of the system's underlying architecture. Based on the system architecture, we present a review of relevant technologies adopted for the proposed content selection system. Afterwards, according to the established concept framework and functionality requirements of the system, we describe the structural details of the system database. Finally, this chapter provides the implementation details for the development of different functional components, such as the content selection component, the selection management component, and the learning style identification component.

4.2 Use Case and System Working Process

As described in the previous chapter, the proposed system is expected to provide a multi-criterion based negotiating mechanism for learners to obtain content selection guidelines. In addition to fully fulfill the fundamental requirements stated in the previous chapter, the proposed system also needs to meet following functional requirements to achieve the overall usability.

- *Management of selection records* - The selection results are expected to be easily managed (e.g. saving, browsing, editing, and deleting) by the learner.
- *Multi-user mode* - The proposed system expects to support multiple users. Different users use different profiles to login and used the system, so that individual learners can have the unique selection collection of their own.

- *LOM instance export* – To more effectively facilitate learner's content selection process, the proposed system is expected to export selected recommendation records to the XML based metadata instances of IEEE LOM specification, so that the learners can use the generated XML files as the concrete filtering criteria to more easily retrieve learning objects from various LOM compatible learning object repositories.

- *Learning style Identification* – Because learners are usually unaware of their learning styles, there is a need for the proposed system to provide a method that can identify the individual learner's learning styles on the fly, so that participating users can more easily determine which type of learners they are with respect to Honey & Mumford's four types of learning styles (activists, reflectors, theorists, and pragmatists).

- *User authentication* – To support the multi-user mode and ensure the system information security, the proposed system needs to provide user login/logout functionalities to realize the user authentication.

Based on the functional requirements presented above, the proposed system is expected to:

- provide user login/logout functionalities to achieve user authentication;
- select values from dynamic and correlated criteria that describe the content;
- save the selection recommendation results;
- modify saved recommendation records;
- delete saved recommendation records;
- identify learning styles of the particular learner; and
- export saved recommendation records to XML metadata instances that are valid with respect to IEEE LOM specification.

The use cases diagram (figure 12) gives an overall view of all functionalities provided by the proposed system.

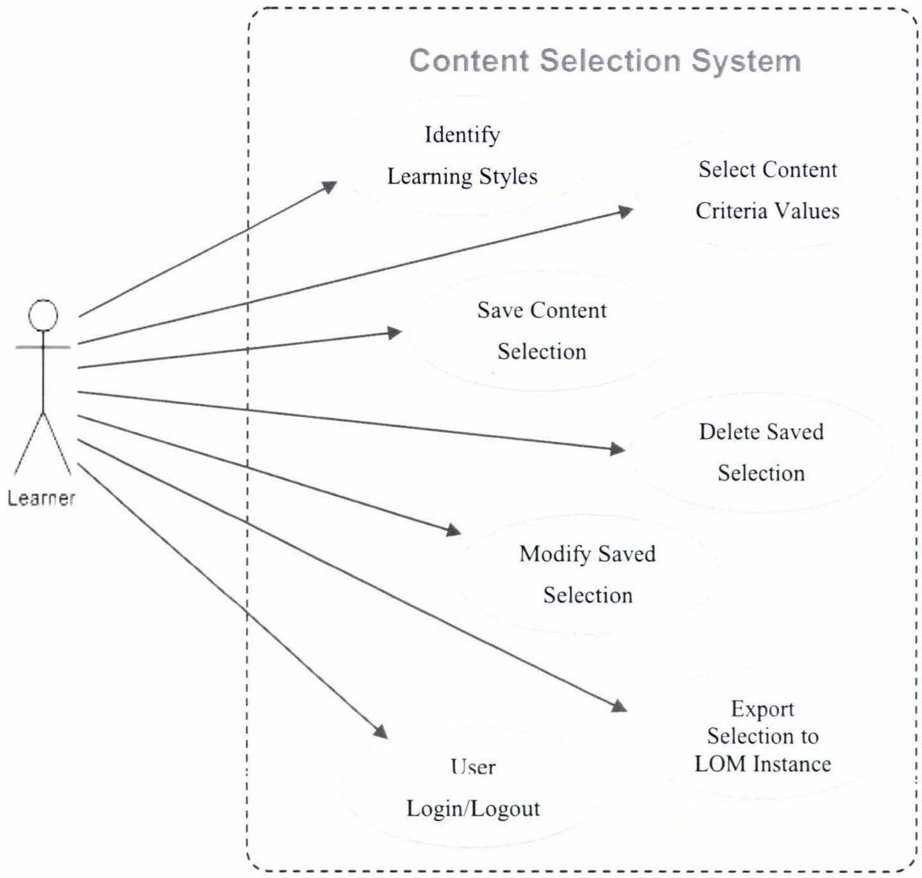

Figure 13 the System Use Case Diagram

The detailed use cases descriptions are presented as follows.

- ***User Login/Logout***

To use the system, the user is prompted to provide his/her user account information, such as user name and password. After the user enters the login credentials, the system checks if the current user is registered. If the system finds such user in the database and the provided password is matched, the user is redirected to content selection page. Otherwise, the user is taken to a registration page and is required to register a new system account.

- ***Select Content Parameter Values***

After the successful login, the learning content selection page is presented to the user. This page provides thirteen correlated parameters for describing a "unit of learning content". The user can access the values of these parameters to obtain recommendations for suitable learning content. While the user is performing the selection operation, detailed description of selected the parameter values will be presented, and values of other correlated parameters will dynamically changed according to the built-in dependency rules between parameters.

- ***Identify Learning Style***

In the content selection page, a web-based Honey & Mumford Learning Style Questionnaire is provided for identifying individual's learning style. During the course of content selection process, the user open the Learning Style Questionnaire page and honestly tick the statements with which he/she agree more than he/she disagree. Then the user's learning style will be automatically calculated according to his/her agreements to those statements. Finally, the user use the calculated learning style as the desired value for the Learning Style parameter.

- ***Save Recommendation***

After the user complete the selection process, the user saves the current selection recommendations to database. The system will give a summary covering all the parameters and present a confirmation dialogue to the user. When the saving action is confirmed by the user, the selection recommendation will be finally saved to the records management database. Afterwards, a redirecting page with three options ("begin a new selection", "continue the current selection", and "go to selection management page") is returned to the user.

- ***Modify Saved Recommendation Record***

Instead of performing the selection from scratch, the user can simply create a copy of a selection record, and modify the selection based on this copy. To use this functionality, the user navigates to the selection management system, and makes a copy of desired selection record. Then the selection page will be presented to the user with the copied parameter values loaded. Based on this selection copy, the user carries out further modifications by changing the values of parameters. Finally, a newly revised selection is saved to the selection management database.

- ***Delete Saved Recommendation Record***

To delete a selection record, the user simply navigates to the selection management page, then, highlight the desired selection record, and perform the delete action. After deletion is confirmed, the selection record will be finally removed from database.

- ***Export LOM Instance***

To use this functionality, the user navigates to the selection management page, then, highlight the desired selection record, and perform the export action. Then, a file download dialogue is displayed. After the user confirms the file download, an XML file containing LOM instance metadata will be finally saved to the user's hard drive.

To more clearly describe how the system works, figure 13 illustrates the overall working flow of the proposed system.

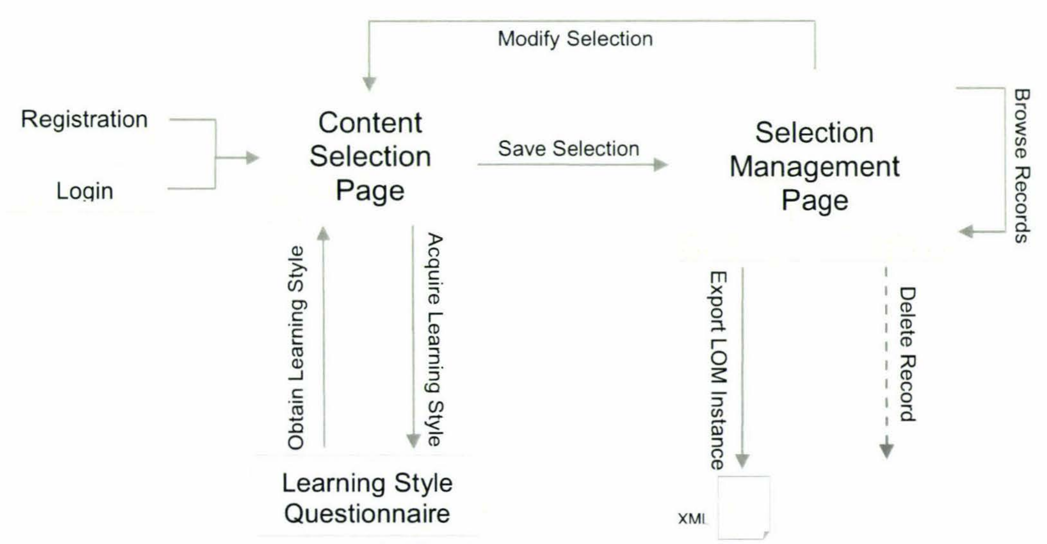

Figure 14 the System Working Flow

Based on the system functionalities described in the use cases and the system working flow diagram, the target user role of the proposed system is the learner that is possibly based on various locations. So, the system needs to provide a convenient way to ensure that it can be accessed by learners from different places. Furthermore, many system functionalities exhibit very strong dynamic interactivities to users. For example, in the content selection component, nearly every feedback that the user makes to the system will cause changes on the parameter contexts due to the complex dependencies between the parameters. Therefore, we also need choose appropriate technologies to implement these sophisticated correlations.

4.3 Implementation Technologies Review

Along with the rapid evolution of internet technologies, the focus of software applications design has been increasingly shifted from building standalone programs to the developments of web-based applications. Especially, with the booming of server-side programming technologies (e.g. Java, PHP, ASP, Ruby, and so on), the development of web-based application has broken the barrier of the static information offering approach. Nowadays, server-side technologies are capable of providing complex, structural, and highly interactive web-based applications that can be universally accessed by people "in any places" and "at any time".

For this reason, we implement the proposed learning content selection system as a web-based application by using recent developed server-side technologies. In this section, we mainly discuss the relevant technologies that are adopted for the development of proposed content selection system.

4.3.1 Microsoft .NET Platform

.NET is Microsoft's strategy for developing large distributed software systems. A core component of .NET is the .NET Framework, a component model for the Internet. A component model allows separate software components written in different languages to be combined to form a functioning system (Watkins et al., 2002). The figure 14 below demonstrates overall structure of the Microsoft .NET Framework.

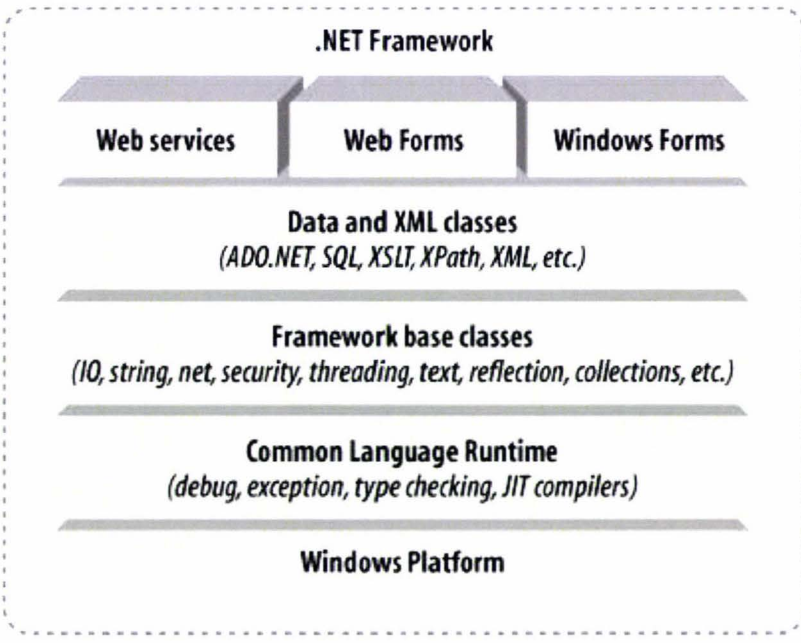

Figure 15 Components of the .NET Framework (Hurwitz, 2005)

As illustrated in the diagram, the .NET infrastructure is essentially a system application that runs on Windows platform. Within the .NET framework, the Common Language Runtime (CLR) is the most important component, which can be roughly comprehended as Java Virtual Machine (JVM). Compared with the single language support of the Java Virtual Machine, the CLR support the interpretations of many different programming languages, such C++, Java, VB, C# and so on. Thus, great flexibilities are presented to programmers who have diverse programming background. On top of the CLR, there are two sets of framework classes, which support input/output functionality, network communications, thread management, text management, reflection functionality, XML manipulation, database access, and so on. Beyond the Framework classes these is another tier of classes developed to support three types of application.

- *Windows Form* – support a set of classes that allow application designers to develop native Windows GUI applications.

- *Web Form* – the key technology behind ASP.NET. It offers a number of classes that allow developers to efficiently develop web-based rich interface applications.
- *Web Service* –includes a set of classes that support the development of lightweight distributed components, which can communicate with each other across heterogeneous operating systems.

4.3.2 Microsoft C#.NET

The Microsoft C#.NET is the key programming language that is newly developed by Microsoft as the main force language in the development of .NET applications. The C# is fully object oriented and type safe. It combines improved syntaxes derived from C++ and Java programming languages, and also inherits some prominent features from these two languages. The C# language could be viewed as having the elegance and simplicity of Java coupled with the power and convenience of C++. According to Mok (2003), C# has following important features.

- A simple, modern, general purpose, object-oriented programming language.
- Provides support for software engineering principles.
- Suitable for building components deployed in distributed environments.
- Supports internationalization.
- Suitable for writing applications for both hosted and embedded systems, ranging from the very large that use sophisticated operating systems, down to the very small having dedicated functions.

4.3.3 Microsoft ASP.NET

Microsoft ASP.NET is a core component of the Microsoft .NET Framework. It is a brand new paradigm for the development of web-based application compared to the old ASP (Active Server Page) programming approach. The ASP.NET provides a cutting edge technology called "Web Form" for developers to efficiently design highly interactive web applications with rich graphic interface enabled. The very essence of the web form technology is making web page controls programmable. The Web Form offers a set of server controls that are similarly mapped the corresponding HTML elements. These controls have properties, methods, and events that developers can manipulate by using server-side programming languages such as C#, VB, C++, Java and so on. Every time when the browser sends requests to the WebForm application, the containing events are raised, methods are invoked, control properties are changed, and eventually the manipulated controls are rendered as HTML contents and are sent back to the browser. Thus developers can build web application just like how they developed traditional windows GUI applications without considering the sophisticated HTTP requests/responses handling processes, so that complex application/page logics can be easily handled. Figure 15 presents the list of the ASP.NET server controls.

Figure 16 the ASP.NET Web Controls (Hurwitz, 2003)

In a Web Form application, the ASP.NET server controls are added in the ASPX page (.aspx file). For each .aspx file, there is a C# class (.cs file) associated with it. The instance of this class contains fields that are fully mapped with the server controls included in the corresponding ASPX page. Changes of status on any field in the class will be directly reflected on the associated .aspx file. Therefore, the developer can flexibly control the page contents by simple manipulate the corresponding code-behind C# class. Figure 16 demonstrates this "Code-Behind" mechanism.

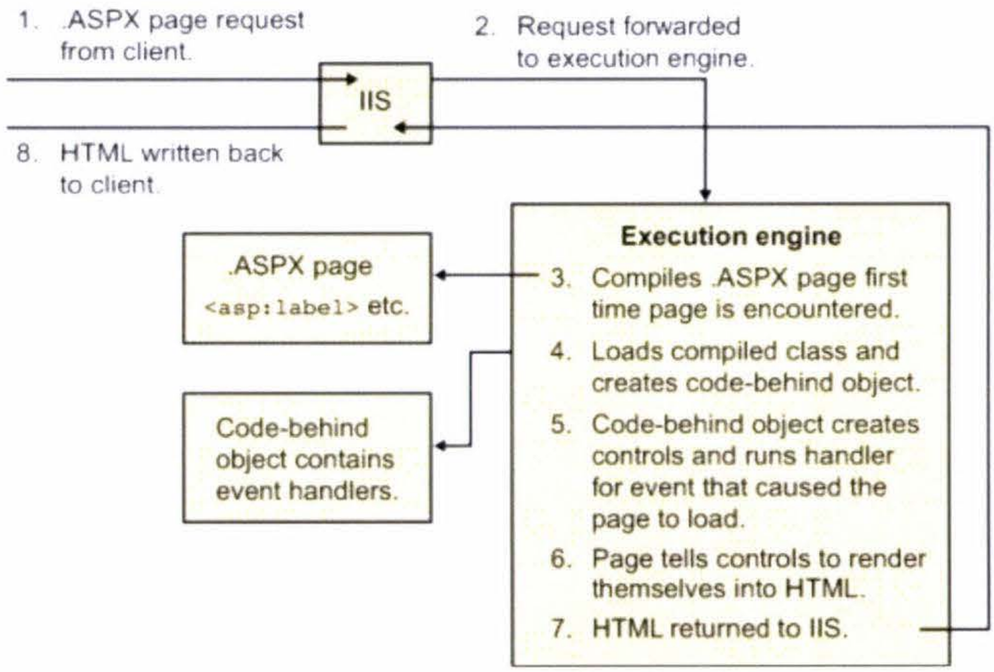

Figure 17 the ASPX page execution Process (Platt, 2003)

4.3.4 Microsoft ADO.NET

The ADO.NET is another key component of the .NET Framework. The ADO.NET (ActiveX Data Objects) is developed to build a bridge between objects in ASP.NET and the back-end database. It provides an object-oriented view into the database, and encapsulates many of the database properties and relationships within ADO.NET objects. Specifically, the ADO.NET provides a set of class libraries to help developers communicate with various data stores from .NET applications. These libraries can be used for connecting to a data source, submitting queries to the database, and processing results retrieved from the database. Basically, ADO.NET libraries are grouped into two parts: the Data Providers and the Data set. Figure 17 presents an overview of the ADO.NET architecture.

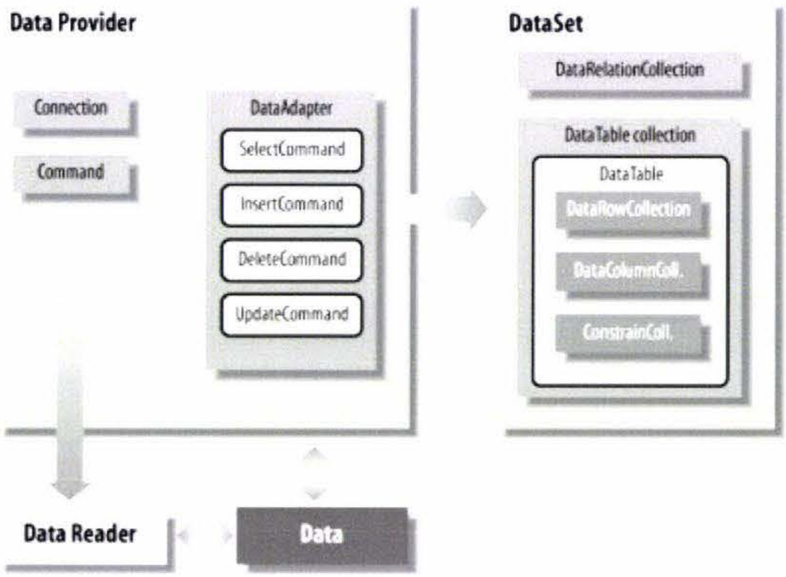

Figure 18 the Overview of ADO.NET Architecture (Hurwitz, 2003)

As shown in the architecture above, the DataSet object provided in ADO.NET contains a set of rows resulting from one or more SQL queries from data sources. It can be viewed as a container for a number of data table objects disconnected from the database. Developers can use these disconnected data cache to sort, search, filter, store pending changes, and navigate through data without having to communicate with a database. After the data manipulation is completed, updated information in the DataSet object will be submitted to the database once for all. Therefore, developers pass less data between the different processes or servers, so that the overhead of data source connection can be considerably reduced.

In the ADO.NET architecture, the Data Provider components are specific to a data source. It is a collection of classes designed to allow developers to communicate with a particular type of data store. The .NET Framework offers four types of Data Providers: Microsoft SQL Server, Oracle, OLE DB, and ODBC. The SQL Server and Oracle Data Providers are respectively designed to communicate with SQL Server and

Oracle databases. The OLE DB .NET data provider allows access to most OLE DB data sources through OLE DB providers. Similarly, the ODBC .NET data provider uses the ODBC drivers to access most ODBC data sources. In addition, other databases (e.g. Sybase, MySQL, and so on) also develop their own .NET data providers. In our proposed system, we use the MySQL .NET Data Provider, because MySQL is chosen as the back-end database. Figure 18 illustrates the different types of .NET Data Providers.

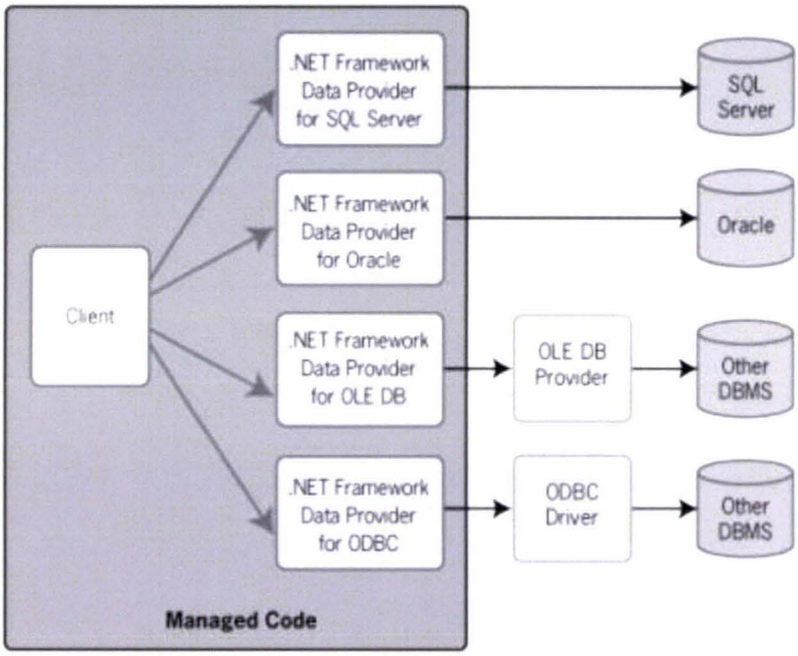

Figure 19 the .NET Data Providers (Chappell, 2006)

4.3.5 MVC Design Pattern

Design patterns are very useful software development paradigms for solving complex design problems if they are used properly. The MVC (Model-View-Controller) design pattern is created by Xerox PARC for Smalltalk-80 in the 1980s. Recently, it is gradually becoming the most popular software development paradigm for web applications design. Earlier web applications are usually developed with old procedural programming languages such as JSP, PHP, ASP, and so on. Data queries and business logic code written by these languages are directly embedded in the web pages mixing with HTML elements. This brings significant maintenance difficulties to developers when the scale and the complexity of the application are increasing. The MVC design pattern is developed to overcome this problem by separating data input, data processing, and data output of an application. According to Sun (2002), the MVC modules are explained as follows.

- *Model* - The model represents application data and the business rules that govern access to and updates of this data.

- *View* - The view renders the contents of a model. It accesses application data through the model and specifies how that data should be presented.

- *Controller* - The controller translates interactions with the view into actions to be performed by the model.

The general concept of the MVC design patter is illustrated as figure 19.

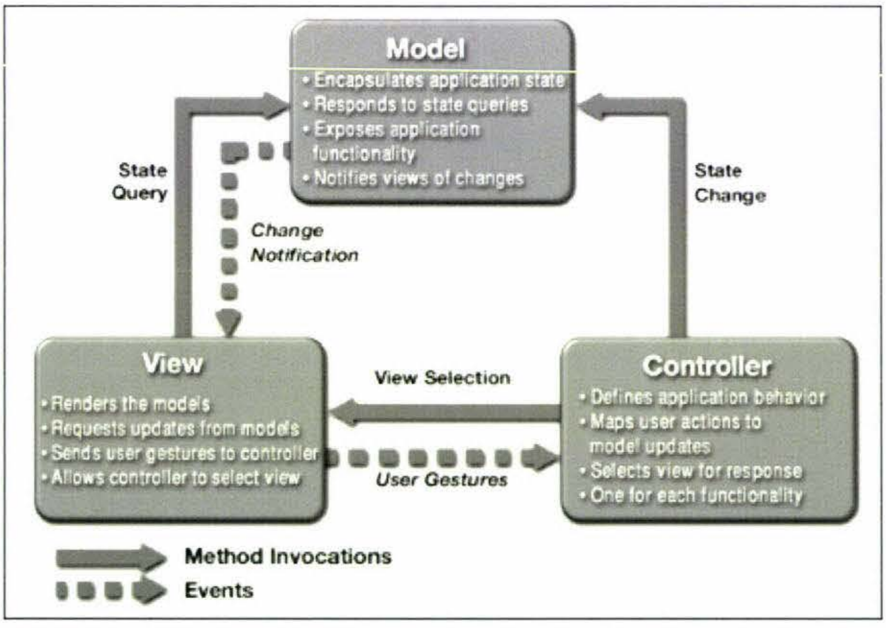

Figure 20 the MVC Design Pattern (Sun, 2002)

By separating the application object model from the user interface, developers can build more reliable and supportable software. The modifications can be independently performed on each component. For example, if the underlining database system is changed, developers only need to modify the *model* part of the application instead of widely revising all pages that contain data access code. Therefore, by following the Model-View-Controller development pattern, applications developers can have greater flexibilities to easily maintain application with large complexities, and to improve the reusability of model components.

ASP.NET provides an effective architecture for implementing MVC design pattern. The ADO.NET library provides data manipulation objects (e.g. DataSet, DataProvider, DataAdapter, and DataReader) for handling the application data and represents the Model component. The View component (user interface) is implemented by using the WebForm server controls in the ASPX page. Finally, The Controller functions and application logics are implemented in the code-behind C# class that is associated with the .aspx page.

4.3.6 XML

According to W3C (2003)'s description, XML, Extensible Markup Language (XML) is a simple, flexible, and standard text format for describing electronic resources. This format is flexible enough to be customized for domains as diverse as web sites, electronic data interchange, vector graphics, genealogy, real-estate listings, object serialization, remote procedure calls, voice-mail systems, and more (Harold, 2003). XML defines a generic syntax used to mark up data with simple, human-readable and computer-readable tags. In addition, the XML specification (DTD and XML Schema) defines basic structural and semantic rules on what/how tags are presented and organized in XML documents. By using the XML specification, individuals or communities may agree to use only certain tags in the XML file in order to fulfill their different needs.

In the e-learning communities, XML is widely used for describing diverse aspects of learning. The educational metadata standards discussed in the literature review chapter are all implemented as XML specification. Thus, XML documents that are valid with respect to the corresponding XML specification represent the instance of a specific learning.

4.3.7 JavaScript

JavaScript is a lightweight, interpreted programming language with object-oriented capabilities (Flanagan, 2001). The client-side JavaScript can be embedded in web pages to enhance static web applications, by providing dynamic and interactive content. JavaScript is now widely supported by various mainstream web browsers, such as IE, Netscape, Mozilla, Opera, and so on. By interacting with the DOM[3] (Document Object Model) tree, developers can use JavaScript to precisely control properties and behaviors of specific HTML elements in a web page. Due to the flexible attributes of JavaScript, the proposed system use JavaScript to provide dynamic descriptions and improve graphical effect of the system's GUI.

4.3.8 MySQL

MySQL is an open source Relational Database Management System (RDBMS) that is built under the GNU Public License (GPL). It is initially developed to fulfill the basic data storage demands of small scale applications. In spite of the lightweight nature of the MySQL database system, several outstanding features shows that MySQL is a competent database system for both commercial and none-commercial applications. According to Kofler (2004), these features include SQL compatibility, transactions, foreign key constraints, platform independence, ODBC connector, user interface, full-text search, and high speed.

In our proposed content selection system we use MySQL as the back-end database system to store the application data, because MySQL provides well customized and fast updated database connector drivers (DataProvider) for the ADO.NET, the

[3] DOM: A generic set of objects, properties, and methods with which developers can use to alter the contents of the HTML page. The DOM is provided by W3C.

ASP.NET application can fully utilize the power of ADO.NET to handle the data manipulations.

4.4 System Architecture

The proposed system is developed as a web application based on classic three-tier architecture following the Model-View-Controller design pattern. Within the system architecture, ASP.NET is used for building the client tier and intermediate tier, which can be respectively mapped to View and Controller components of the MVC design pattern. The ADO.NET and MySQL database together form the back-end data management tier, which is mapped to the Model component of the MVC design pattern. Figure 20 illustrates overall system architecture.

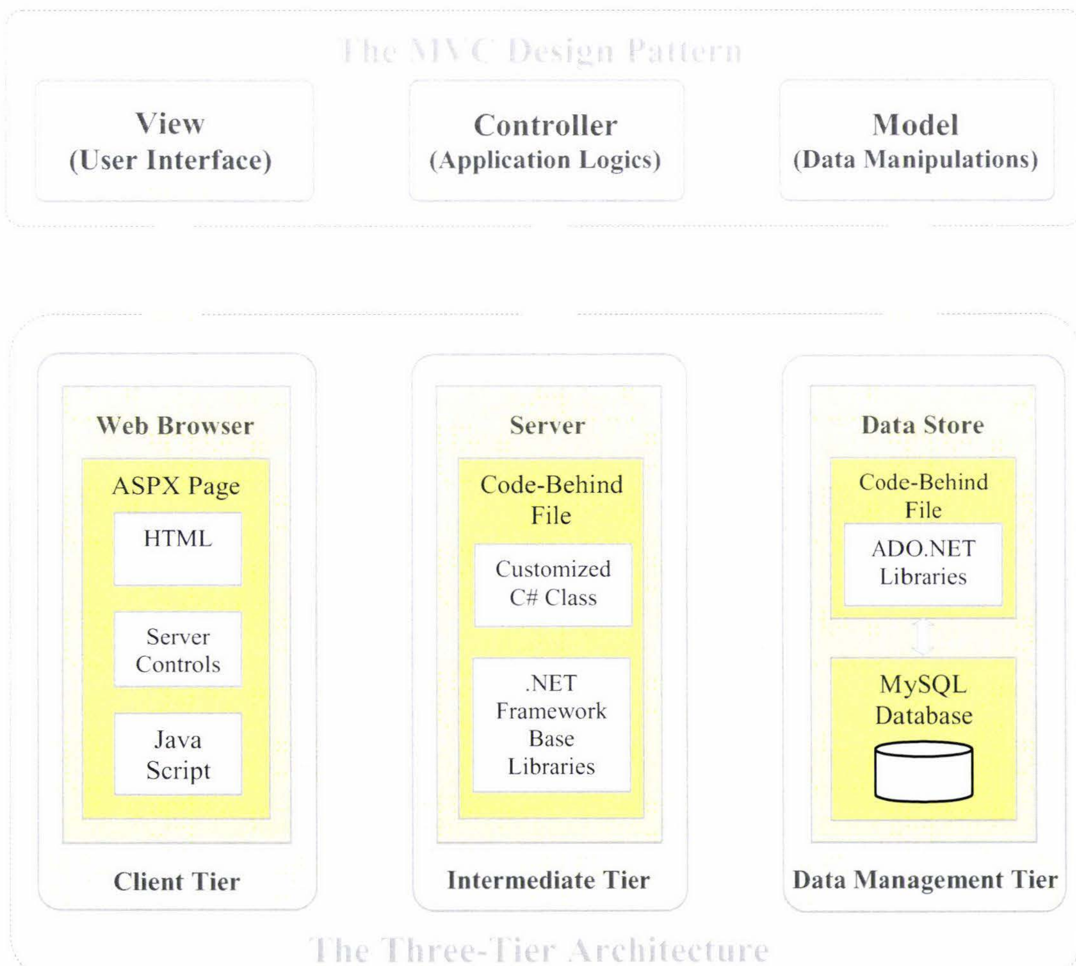

Figure 21 the System Architecture

As illustrated in the diagram above, the architecture of the proposed system is generally divided in three processing tiers. They are the Client tier, the Intermediate tier, and the Data Management tier. Each tier in the system architecture can respectively correspond to the particular component of the Model-View-Controller design pattern.

- ***Client Tier***

The Client Tier mainly provides the system's user interface that can be viewed in various web browsers. It is the "View" of the system. In this tier, we use ASPX pages to implement the five system user interface components. They are *user login*, *user registration*, *content selection*, *learning style questionnaire*, and *selection management*. In the ASPX pages, we use Server Controls and pure HTML to build the user interface content. Plus, JavaScript is embedded in the pages to improve the functionalities of the user interface, such as client-side form validation, system notification, helps prompting, dependencies highlighting and so on.

- ***Intermediate Tier***

The Intermediate Tier is mainly responsible for handling the application logics and controlling the representation of the user interface. It can be considered as the "Controller" of the system. This tier is implemented with C# programs contained in the "Code-Behind" files (with .cs extension). Because each ASPX page in the Client Tier (View) is controlled by its corresponding "Code-Behind" C# class, five C# programs need to be created for respectively handling application logics of the five user interface components. By utilizing the base libraries provided by .NET Framework, we develop the five C# classes to process the system logics, which include handling page events, managing application sessions, authenticating users, invoking data accessing models, manipulating criteria dependencies, and so on.

- ***Data Management Tier***

The Data Management Tier mainly provides the data storage and data manipulation functionalities for the proposed system. Within this tier, the MySQL database system is used to store application data, such as user account information, criteria descriptions, selection records, criteria dependency rules, and so on. While the ADO.NET provides objects for data manipulating jobs, such as database connecting, data retrieving/updating/deleting, transactions controlling, and so on. The ADO.NET and the MySQL database are grouped together to form the "Model" of the system.

4.5 Implementation Details

4.5.1 System Database Design

The design of the system database is the core task for the implementation of the proposed content selection system. In addition to save the application data such as user information, selection records, criteria descriptions, the parameter dependency rules are stored in the database as well. According to the discussion in the "Concept design and Analysis" chapter, complex dependency rules are developed to illustrate the correlations between proposed parameter that describe the unit of a learning content. Although it is handier to use C# language to implement these dependency rules by taking advantages of its Object-Oriented capability, hard-coding rules into the classes will raise a scalability issue. If new rules or parameters need to be included, the classes that implement these rules need to be re-rewritten, and more importantly, it is very difficult to develop extension tools that are used to add new parameters or dependency rules by dynamically modifying C# source code. For this reason, we store the identified parameters in the data tables, and use foreign keys to address their dependency rules, so that new criteria or dependency rules can be more easily added in the future by dynamically creating new columns in the table. Based on the criteria dependency rules developed in the "Concept design and Analysis" chapter, table 8 presents the data tables designed for addressing the criteria dependency rules.

Table 8 the Data Tables for Addressing Dependency Rules

Aggregation_InteractivityLvel				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
ALIL_ID	VARCHAR(20)	✓	✓	

Aggregation_Level	VARCHAR(1)	✓		✓
Interactivity_Level	VARCHAR(15)	✓		✓

Aggregation_Level

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Aggregation_Level	VARCHAR(1)	✓	✓	
Description	TEXT	✓		

Aggregation_Structure

Column Name	Data Type	Not Null	Primary Key	Foreign Key
ALSID	VARCHAR(20)	✓	✓	
Aggregation_Level	VARCHAR(20)	✓		✓
Structure	VARCHAR(15)	✓		✓

Definition_Example

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Definition_Example	VARCHAR(30)	✓	✓	
Description	TEXT	✓		

Domain

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Learning_Domain	VARCHAR(15)	✓	✓	
Description	TEXT	✓		

Domain_Resource

Column Name	Data Type	Not Null	Primary Key	Foreign Key
DR_ID	INTEGER	✓	✓	
Learning_Domain	VARCHAR(20)	✓		✓
Learning_Resource_Type	VARCHAR(25)	✓		✓

Domain_Service

Column Name	Data Type	Not Null	Primary Key	Foreign Key
DS_ID	INTEGER	✓	✓	
Learning_Domain	VARCHAR(35)	✓		✓
Service_Facility	VARCHAR(20)	✓		

Interactivity_Level

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Interactivity_Level	VARCHAR(15)	✓	✓	
Description	TEXT	✓		

Inrtactivity_Type

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Interactivity_Type	VARCHAR(10)	✓	✓	
Description	TEXT	✓		

InteractivityLevel_Density

Column Name	Data Type	Not Null	Primary Key	Foreign Key
ILSD_ID	INTEGER	✓	✓	
Interactivity_Level	VARCHAR(10)	✓		✓
Semantic_Density	VARCHAR(10)	✓		✓

Resource

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Learning_Resource_Type	VARCHAR(25)	✓	✓	
Description	TEXT	✓		

Resource_Example

Column Name	Data Type	Not Null	Primary Key	Foreign Key
LRTDE_ID	VARCHAR(50)	✓	✓	
Learning_Resource_Type	VARCHAR(20)	✓		
Definition_Example	VARCHAR(30)	✓		✓

Resource_InteractivityLevel

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Learning_Resource_Type	VARCHAR(20)	✓	✓	✓
Interactivity_Type	VARCHAR(15)	✓		✓

Role_Part

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Role_Part	VARCHAR(15)	✓	✓	
Description	TEXT	✓		

Semantic_Density

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Semantic_Density	VARCHAR(15)	✓	✓	
Description	TEXT	✓		

Service

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Service_Facility	VARCHAR(30)	✓	✓	
Description	TEXT	✓		

Structure

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Structure	VARCHAR(15)	✓	✓	
Description	TEXT	✓		

Style

Column Name	Data Type	Not Null	Primary Key	Foreign Key
Learning_Style	VARCHAR(15)	✓	✓	

Description	Text	✓		

Style_Resource				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
ID	INTEGER	✓	✓	
Learning_Style	VARCHAR(15)	✓		✓
Learning_Resource_Type	VARCHAR(30)	✓		✓

Style_Role				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
LSRP_ID	INTEGER	✓	✓	
Learning_Style	VARCHAR(15)	✓		✓
Role_Part	VARCHAR(15)	✓		✓

Style_Service				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
LSSF_ID	INTEGER	✓	✓	
Learning_Style	VARCHAR(20)	✓		✓
Service_Facility	VARCHAR(45)	✓		✓

Style_Timing				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
LSTC_ID	INTEGER	✓	✓	
Learning_Style	VARCHAR(15)	✓		✓
Time_Control	VARCHAR(15)	✓		✓

Theory				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
Learning_Theory	VARCHAR(60)	✓	✓	
Description	TEXT	✓		

Theory_Domain				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
LDLT_ID	INTEGER	✓	✓	
Learning_Theory	VARCHAR(50)	✓		✓
Learning_Domain	VARCHAR(20)	✓		✓

Timing_Control				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
Time_Control	VARCHAR(15)	✓	✓	
Description	TEXT	✓		

Figure 21 presents the ER diagrams to illustrate the structure of the criteria dependency rules in a graphic way.

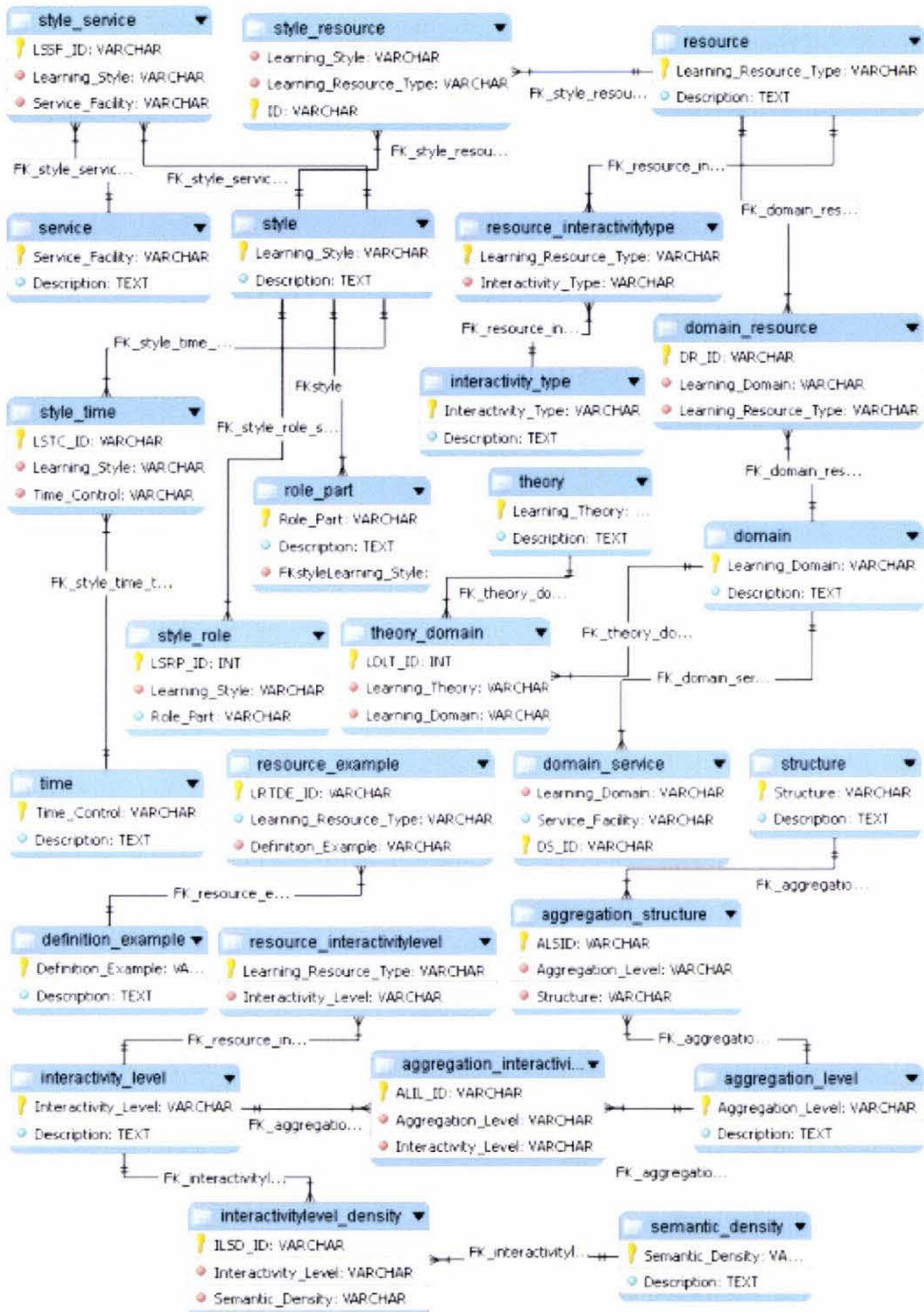

Figure 22 the ER Diagrams of Dependency Rules Data Table

Based on the proposed functional requirements, the system is expected to support multi-user mode, which means an individual user should use his/her own account for the system, and is able to manage his/her own saved selection records as he/she is the only user of the system. Therefore, besides the user account information, the selection results that are associated with particular user account need to be saved to the database. Table 9 shows the design of the user information table and the selection records table.

Table 9 the User Information Table and the Selection Records Table

User				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
User_ID	VARCHAR(45)	✓	✓	
User_Name	VARCHAR(45)	✓		
Password	VARCHAR(45)	✓		
Selection				
Column Name	**Data Type**	**Not Null**	**Primary Key**	**Foreign Key**
SID	INTEGER	✓	✓	
User_ID	VARCHAR(45)	✓		✓
Learning_Domain	VARCHAR(35)	✓		
Learning_Theory	VARCHAR(60)	✓		
Learning_Style	VARCHAR(20)	✓		
Service	VARCHAR(45)	✓		
Role_Part	VARCHAR(20)	✓		
Timing_Control	VARCHAR(20)	✓		
Learning_Resource_Type	VARCHAR(35)	✓		
Definition_Example	VARCHAR(60)	✓		
Interactivity_Type	VARCHAR(20)	✓		
Aggregation_Level	VARCHAR(15)	✓		
Interactivity_Level	VARCHAR(20)	✓		
Semantic_Density	VARCHAR(20)	✓		
Structure	VARCHAR(20)	✓		
Learning_Scenario	TEXT	✓		

Figure 22 presents the ER diagrams to graphically illustrate how the selection records are associated with particular user account.

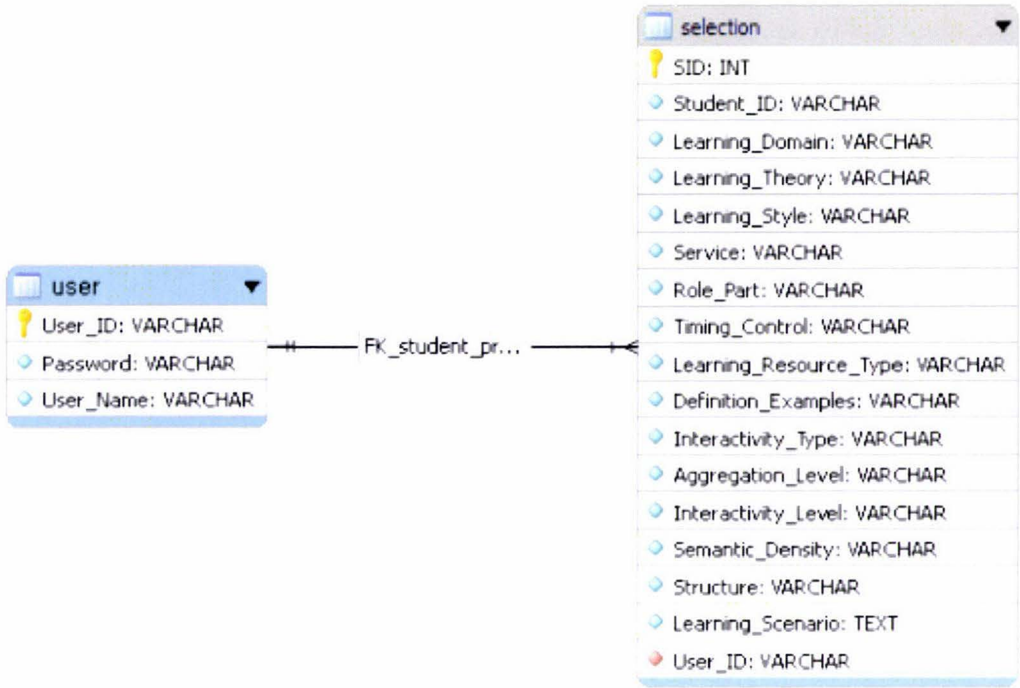

Figure 23 the Selection Records - User Account Association

4.5.2 Content Selection Page Implementation

The "content selection" page is the core component of the proposed system. It is developed to provide a multi-parameter based negotiation mechanism for learners to select suitable content best meet their needs. The "content selection" page is implemented into two components: an ASPX page (view) is developed as the front GUI, and a code-behind C# class (controller) that is associated with the page is developed for processing application logics. As shown in figure 23, the selection page uses the DropDownList server controls to emulate selection criteria. The options in the DropDownList therefore represent the values of the criteria. The logic processing within the "content selection" page is entirely based on an event driven paradigm. It means that the action that the user performs on the page will raises particular event and the ASP.NET application's job is to determine how to handle the raised events. When the user selects a value from a particular DropDownList, an event of changing the DropDownList's value is raised. The "code-behind" C# class captures this event, and provides a handler method responding to it, and updates values in relevant parameters. Figure 23 illustrates this event based development paradigm.

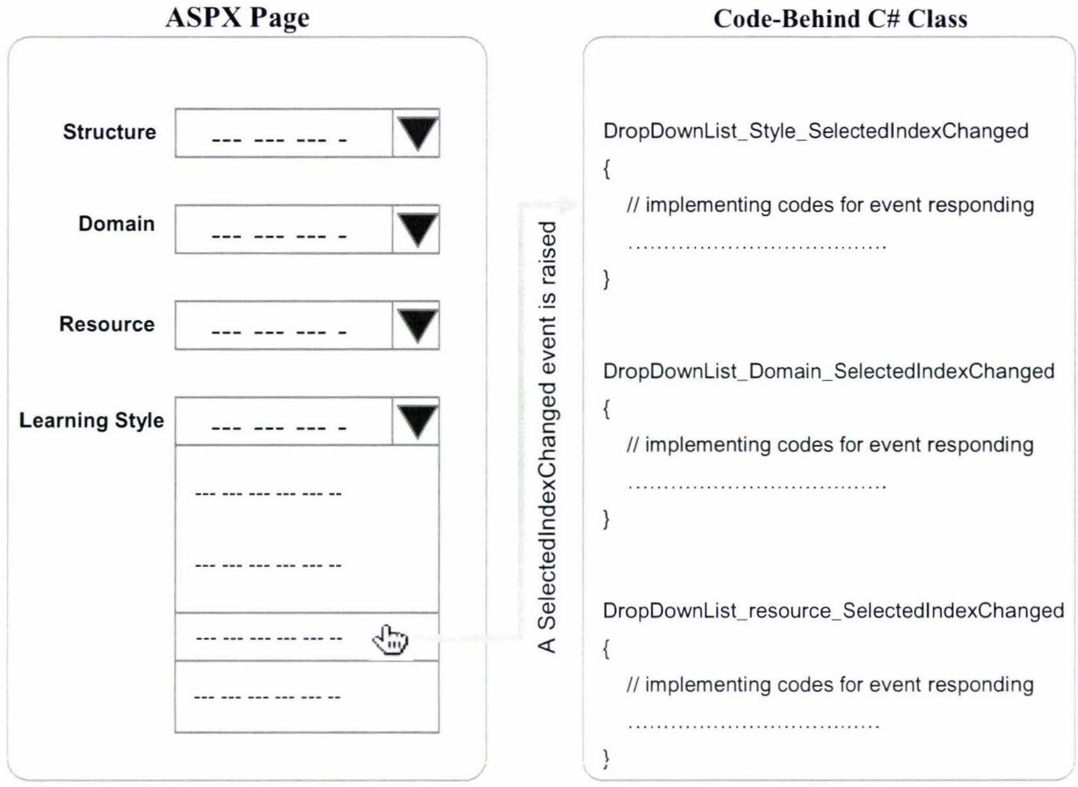

Figure 24 the Event Based Development Paradigm

According to the criteria dependency rules defined in the "Concept Design and Analysis" chapter, a change of the value on a certain criteria may cause changes of availabilities or values of other criteria. This dynamic process is perfectly emulated with the adoption of the event driven development paradigm and the "Code-Behind" technology provided by ASP.NET. Based on the criteria dependency rules, there are thirteen parameters defined for describing the selection process. Therefore, we implement thirteen event handler methods corresponding to their respective criteria.

Following the implementation of the *view* and the *controller* components of the content selection page, the *model* of the page needs to be developed. Within the event handlers, are the actual operations for searching right dependency rules stored in database and returning proper values to the influenced parameters. To achieve these procedures, the controller applications in the event handlers need to call the model components for retrieving proper data. Based on the defined criteria dependency rules, we develop the "SelectionModel" class as the model components for the "content selection page", which are listed as table 10.

Table 10 the SelectionModel Class

SelectionModel Class		
Method Name	**Return Type**	**Description**
GetTheory(string domain)	ArrayList	Based on dependency rules, particular learning theories are suitable in specific learning domain. This method returns available learning theories that are associated with given learning domain.
GetDomainResourceSet(string domain)	Set	Based on dependency rules, particular learning resource types are suitable in specific learning domain. This method returns available learning resource types that are associated with given learning domain.
GetService(string style)	ArrayList	Based on dependency rules, learners with different learning style prefer different service facilities in learning. This method returns preferred service facilities according to the learner's learning style.
GetRolePart(string style)	ArrayList	Based on dependency rules, learners with different learning styles prefer self-guided learning or following the instructor's coaching. This method returns the preferred participating role according the learner's learning style.
GetTiming(string style)	ArrayList	Based on dependency rules, learners with different learning styles prefer controlling the learning duration by themselves, or learning under time constraint. This method returns the timing control according to the given learning style.
GetStyleResourceSet (string style)	Set	Based on dependency rules, learners with different learning style prefer different learning resource types. This method returns the learner's preferred learning resource types according the given learning style.

GetExample(string resource)	ArrayList	Based on dependency rules, diverse learning objects belong to specific learning resource type. This method returns possible learning object instances for the given learning resource type.
GetStructure(string aggregation)	ArrayList	Based on dependency rules, the organizational structure of a learning object is influenced by its aggregation level. This method returns the structure of a learning object based on its aggregation level.
GetInteractivity(string aggregation)	ArrayList	Based on dependency rules, the interactivity level of a learning object is also influenced by its aggregation level. This method returns the interactivity level of a learning object based on its aggregation level.
GetSemantic(string interactivity)	ArrayList	Based on dependency rules, the semantic density of a learning object is influenced by its interactivity level. This method returns the semantic density of a learning object based on its interactivity level.
SaveResults( )	Boolean	This method is responsible for saving current selection context to system database.

According to the descriptions in table 10, the "SelectionModel" class serves as the model of the "content selection page". By taking the selected parameter value as the method input, the encapsulated methods are developed to obtain the dependent values of other influenced parameters according to the dependency rules retrieved from the system database. These obtained values are returned to the controller application (event handlers), and eventually, the controllers render them into the view (ASPX page) of the system. Because the data manipulation tasks are embedded in the model components, the controller applications do not need to involve any data accessing operation.

In each method of the "SelectionModel" class, the ADO.NET data manipulation objects are used to access system database and retrieve stored dependency rules. Figure 24 presents example code to demonstrate the implementation of the ADO.NET for accessing the system database.

```
public ArrayList GetService(string style) {

    /* Create an ArrayList collection object to for holding retrieved data. **/
    ArrayList ServiceList = new ArrayList( );

    /* initializing database connection string, such as database
     *  name, server name, user name, password, and so on.
    **/
    myConnectionString = "Database=DBJian;Data Source=123.342.125.1;"
                              +"User Id=Jian;Password=pass12345";

    /* Define a connection. **/
    MySqlConnection myConnection = new MySqlConnection(myConnectionString);

    /* Define query string: Get preferred values of service facility parameter according to the
     * given learning style.
    **/
    string serviceQuery = "SELECT Service FROM Style_Service WHERE Learning_Style="+style;

    /* Create a MySqlCommand object for executing the query above. **/
    MySqlCommand myCommand = new MySqlCommand(serviceQuery);

    /* Assign the create connection to this MySqlCommand object. **/
    myCommand.Connection = myConnection;

    myConnection.Open( ); // Open the connection to the database.

    MySqlDataReader myReader; // Create a DataReader object to read data from query result.

    /* Execute the data query and save the results to the DataReader. **/
    myReader = myCommand.ExecuteReader( );

    try{
      while(myReader.Read( )) {
        /* Iteratively retrieve data from the DataReader and store it into the ArrayList object. **/
        ServiceList.Add(myReader.GetString(0));
      }
    }
    finally{

        myReader.Close( ); // Close the DataReader.

        myConnection.Close( ); // Close the database connection.
    }

    return ServiceList;

}
```

Figure 25 the Example Code for Implementing ADO.NET Data Access

Based on the criteria dependency rules, disparate learning resource types might be recommended based on two distinct parameters – Learning Style and Learning Domain. In order to resolve this dependency conflict, we implement the return type of the "GetStyleResourceSet (string style)" and the "GetDomainResourceSet (string domain)" method as a customized Set object (see table 10). Thus the controller applications can conveniently take the union of these two sets as the final recommended values for the Learning Resource Types parameter.

4.5.3 Learning Style Questionnaire Implementation

According to the functional requirement specified in the system framework, a web-based Honey & Mumford Learning Style Questionnaire is provided in the "content selection" page for identifying current user's preferred learning style.

By taking advantages of the rationale of Honey & Mumford Learning Style Questionnaire, we implement a web-based questionnaire to explore the learner's learning style preferences by presenting 80 questions (see appendix B); the numbers of the questions are sorted in a fixed order; every 20 question statements are associated with each of the four types of learning styles (activists, reflectors, theorists, and pragmatists). The learner scores one point for each statement he/she ticked. Table 11 shows which question statements contribute points for which learning style type.

Table 11 the Point Contributing Questions for the Associated Learning Style (Honey & Mumford, 1992)

Learning Style	Question Numbers
Activists	2, 4, 6, 10, 17, 23, 24,32, 34,38, 40, 43, 45, 48, 58, 64, 71, 71, 74, 79
Reflectors	7, 13, 15, 16, 25, 28, 29, 31, 33, 36, 39, 41, 46, 52, 55, 60, 62, 66, 67, 76
Theorists	1, 3, 8, 12, 14, 18, 20, 22, 26, 30, 42, 47, 51, 57, 61, 63, 68, 75, 77, 78
Pragmatists	5, 9, 11, 19, 21, 27, 35, 37, 44, 49, 50, 53, 54, 56, 59, 65, 69, 70, 73, 80

To ensure the proper measurement, the learner is required to honestly answer these questions, and tick the statements with which he/she agrees more than he/she disagrees. The numbers of the ticked question statements for each learning style type will be compared to a "general norm" that is established based on 3500 individuals' scores in the learning style questionnaire. Table 12 describes the rationale of the "general norm".

Table 12 the General Norm based on the Population of 3500 (Honey & Mumford, 1992)

	Activists	**Reflectors**	**Theorists**	**Pragmatists**
Very strong Preference	20 19 18 17 16 15 14 13	20 19 18	20 19 18 17 16	20 19 18 17
Strong preference	12 11	17 16 15	15 14	16 15
Moderate preference	10 9 8 7	14 13 12	13 12 11	14 13 12
Low preference	6 5 4	11 10 9	10 9 8	11 10 9
Very low preference	3 2 1 0	8 7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	8 7 6 5 4 3 2 1 0

For example, within the total ticked questions statements, if 16 statements are identified belonging to the "Activists" learning style, the learner has very strong preferences to be the activists type of learners; if 10 statements are identified belonging to the "Theorists" learning style, the learner has low preferences to be the theorists type of learners.

In this research, an ASPX page (ls_questionnaire.aspx) and its associated code-behind C# class are developed to implement the learning style questionnaire. In the code-behind class, we implement four ArrayList object to contain the questions that belong to four type of learning styles. After the questionnaire is submitted, the ticked question numbers are respectively compared to the numbers held by the four ArrayList objects. By performing this operation, the amount of the questions that are matched to their associated learning style type is counted. Finally, the count of the questions is compared to the general norm so as to generate the learning style recommendations for the leaner. Figure 26 presents a syntactical expression to demonstrate the core logic for the implementation of the learning style questionnaire.

```
Define the ActivistsList as an ArrayList;
Define the ActivistsNumbersCounts as an Integer = 0;
Define the ActivistsPreference as a String = null;
ActivistsList.Add(20 question numbers that are associated with the Activists type);

for each (Statement Number in Ticked Questions){
        if (ActivistsListis contains the Statement Number) {
                ActivistsNumbersCounts++;
        }
}
if (13 ≤ ActivistsNumbersCounts ≤ 20) {
        ActivistsPreference = "Very Strong Preference";
}

if (11 ≤ ActivistsNumbersCounts ≤ 12) {
        ActivistsPreference = "Strong Preference";
}

if (7 ≤ ActivistsNumbersCounts ≤ 10) {
        ActivistsPreference = "Moderate Preference";
}

if (4 ≤ ActivistsNumbersCounts ≤ 6) {
        ActivistsPreference = "Low Preference";
}

if (0 ≤ ActivistsNumbersCounts ≤ 3) {
        ActivistsPreference = "Very Low Preference";
}
Same approaches can be applied to identify other learning styles...
```

Figure 26 the Logic Expression for the LS Questionnaire Implementation

4.5.4 The Implementation of the Selection Management Component

According to the definition of the system functionalities, the user has the abilities to manage saved selection records. These management functionalities include browsing, modifying, and deleting selection records. To implement the selection management component, an ASPX page (selection_management.aspx) and its code-behind C# class are developed. In the ASPX page, the DataGrid server control is used to display selection records retrieved from the *user* and *selection* data table. The DataGrid server control displays data records fetched from database and offers various event handlers for data display and data edit, such as binding data from data table, sorting displayed data, deleting displayed data, synchronizing displayed data with database, and so on.

To implement the records browsing and deleting functionalities, the code-behind class captures the *DataGrid_DetailsCommand* event and the *DataGrid_DeleteCommand* event from the DataGrid server control when the user is respectively clicking the details link and the delete link on a DataGrid row. Within these two event handlers, actual data manipulation applications are respectively implemented with ADO.NET objects. Figure 26 and figure 27 provide the core code for respectively demonstrating the implementations of records browsing and deleting.

Sometimes the user prefers to carry out the selection process based on an existing selection record rather than starting on the selection from scratch. For this purpose, the selection management component provides the record modification functionality with which user can use to modify an existing selection by importing a copy of the selection record into the selection page. Firstly, the parameter values of a selection record are retrieved from the system database, and are stored in the application session object. Afterwards, the parameter values are respectively released from the session object (Application.Session) to their corresponding parameter DropDownLists in the "content_selection" page. This process involves the re-invocations of the data manipulation methods in the "SelectionModel" class (see table 10), so as to maintain the values context of the parameters.

```
/* Retrieve all parameter values of the currently selected selection record . **/
private void DataGrid_DetailsCommand(object source, DataGridCommandEventArgs e)
{
   /* Create an ArrayList collection object to for holding retrieved data. **/
   ArrayList DetailsList = new ArrayList( );

   /* initializing database connection string, such as database
    * name, server name, user name, password, and so on.
   **/
   myConnectionString = "Database=DBJian;Data Source=123.342.125.1;"
                         +"User Id=Jian;Password=pass12345";

   /* Define a connection. **/
   MySqlConnection myConnection = new MySqlConnection(myConnectionString);

   /* Define query string: Get all parameter values of the currently selected
    * selection records.
   **/
   string serviceQuery = "SELECT Learning_Domain, Learning_Theory, Learning_Style,"
                         +"Service, Role_Part, Timing_Control, Learning_Resource_Type,"
                         +"Definition_Example, Interactivity_Type, Aggregation_Level,"
                         +"Interactivity_Level, Semantic_Density, Structure, Learning_Scenario"
                         +" FROM Selection WHERE SID="
                         +String.Parse(e.Item.ItemIndex);

   /* Create a MySqlCommand object for executing the query above. **/
   MySqlCommand myCommand = new MySqlCommand(serviceQuery);

   /* Assign the create connection to this MySqlCommand object. **/
   myCommand.Connection = myConnection;

   myConnection.Open( ); // Open the connection to the database.

   /* Execute the data query and save the results to the DataReader. **/
   myReader = myCommand.ExecuteReader( );

   try{
     while(myReader.Read( )) {
       /* Iteratively retrieve data from the DataReader and store it into the ArrayList object. **/
       DetailsList.Add(myReader.GetString(0));
     }
   }
   finally{

       myReader.Close( ); // Close the DataReader.

       myConnection.Close( ); // Close the database connection.
   }
}
```

Figure 27 the Example Code for Retrieving the Details of Selected Records

```
/* Delete the currently selected record . **/
private void DataGrid_DeleteCommand(object source, DataGridCommandEventArgs e)
{
  /* initializing database connection string, such as database
    * name, server name, user name, password, and so on.
   **/
   myConnectionString = "Database=DBJian;Data Source=123.342.125.1;"
                        +"User Id=Jian;Password=pass12345";

   /* Define a connection. **/
   MySqlConnection myConnection = new MySqlConnection(myConnectionString);

   /* Define query string: Delete the currently selected record.
   **/
   string serviceQuery = "DELETE FROM Selection WHERE SID="
                        +String.Parse(e.Item.ItemIndex);

   /* Create a MySqlCommand object for executing the query above. **/
   MySqlCommand myCommand = new MySqlCommand(serviceQuery);

   /* Assign the create connection to this MySqlCommand object. **/
   myCommand.Connection = myConnection;

   myConnection.Open( ); // Open the connection to the database.

   try{
     myCommand.ExecuteNonQuery( );
   }
   finally{

      BindGrid( ); // Refresh the DataGrid table.

      myReader.Close( ); // Close the DataReader.

      myConnection.Close( ); // Close the database connection.
   }
}
```

Figure 28 the Example Code for Deleting Selected Records

4.5.5 Integration with XML

As described in the concept framework, saved selections can be used as the content filtering criteria for searching resources from learning objects repositories. Hence, the "XML export" functionality is implemented in the selection management component. By using this functionality, values of the LOM exclusive parameters in the selected record can be exported as an XML file, which is valid with respect to the IMS LOM metadata schema, because the learning objects in most repositories are implemented by LOM. To achieve this functionality, the XML Serialization mechanism is implemented. By using the XML manipulation objects provided in the ADO.NET libraries, we produce a serialize-able class (Imslom.cs) (figure 29) that is fully mapped with the structure of IMS LOM schema. Therefore, the instance of the "Imslom" class can be mapped to the instance XML file of the LOM schema. After the parameter values are retrieved from database and are assigned to the "Imslom" object, the "Imslom" object performs a serialization operation to generate the XML file. The benefit of this approach rests with the ease of extensions. If new LOM elements are introduced in the future, only a one line values assignment code needs to be added and the rest of the implementations of this functionality will remain unchanged. Figure 28 presents the example code to demonstrate the implementation of the serialization process.

```
Imslom myLom = new Imslom( ); // Greate the Lmslom object.

/* Assign the parameter value to the crrespoding propertise of the object**/
myLom.educational.interactivitylevel.value.langstring.Value = Session[ interactivitylevel ];

/* Assign the parameter value to the crrespoding propertise of the object**/
myLom.educational.interactivitytype.value.langstring.Value = Session[ interactivitytype ];

/* Assign the parameter value to the crrespoding propertise of the object**/
myLom.general.structure.value.langstring.Value = Session[ structure ];

/* Assign the parameter value to the crrespoding propertise of the object**/
Keep assigning the rest values ............

/* Initialize the Serializer by making it specifically handle the Imslom type**/
XmlSerializer serializer = new XmlSerializer(typeof(myLom));

   using (FileStream stream = File.OpenWrite("selection.xml")) {

     /* Serialize the object to the XML file**/
     serializer.Serialize(stream,myLom);

   }

Codes taking care of the file download operation..........
```

Figure 29 the Example Code for implementing the XML Serialization

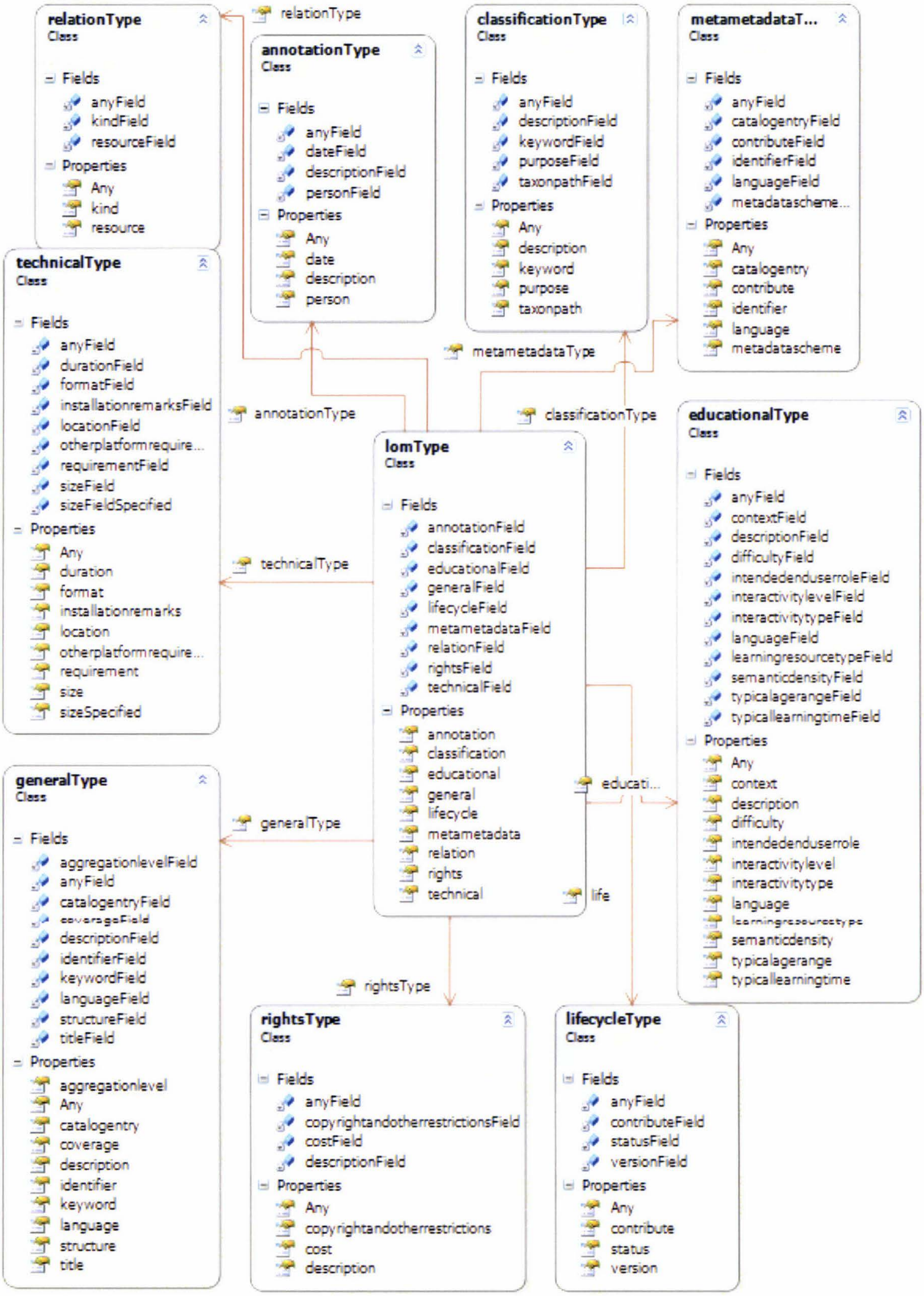

Figure 30 the Class Diagram of the Serializable LOM class

4.6 Summary

In this chapter, we mainly described the comprehensive details of the system implementation process. In the first step of the system implementation, use cases are used to illustrate the desired functionalities (e.g. Identifying Learning Styles, Saving Content Selection, Modifying Saved Selection, and so on) that the proposed system needs to provide. After the system working process is designed, the relevant software technologies that are used for implementing the system are reviewed. The Microsoft .NET Framework is used for building the underlying architecture of the system. For achieving the scalabilities and the ease of extensions, the proposed system is developed as a web application based on three-tier architecture. Each tier of the system is mapped with the particular component of the Model-View-Controller design patter, so as to achieve the ease of maintenances and the reusability of the system. Generally, three main functional components are implemented in the proposed system. They are the Content Selection page, Learning Style Questionnaire page, and Selection Management page. By using the WebForm technology offered by ASP.NET, the server controls are used to implement the components' GUI (View), and the code-behind classes that are written with C# language are developed to handle the application logics. The ADO.NET is mainly used for developing the data manipulation objects, which serve as the Model of the system components.

Chapter 5 System Prototype

5.1 Introduction

In this chapter, we first describe the system deployment process of the implemented system. After that, the detailed description along with the interface screenshots is provided to demonstrate the usages of the system.

5.2 System Deployment and Distribution

The proposed system is implemented as a client-server based web application driven by server-side technologies (Microsoft .NET platform). To successfully run the system, following software or server components must be used:

- Windows Server 2000 or above
- Microsoft .NET Framework (version 1.1)
- Microsoft Internet Information Service (IIS) (5.0 or above)
- MySQL database management system
- MySQL .NET Connector

Because the .NET Framework is a Microsoft's technology, the Windows based server must be used to host the application. In the Windows Server, the Microsoft Internet Information Service must be installed, so that it can serve as the container for hosting the web application. If the Windows 2000 Server is used as the server host, the .NET Framework has to be installed separately. The Window Server with later versions has the built-in .NET Framework, so that it can be directly used without further upgrade. In addition to installing the MySQL database management system to store the application data, the MySQL .NET Connector has to be manually installed to enable the communication between .NET Framework and the database. After all required server components are successfully installed, a virtual directory needs to be created in the default directory of the "IIS" (generally C:\Inetpub\wwwroot), and then copy the implemented system application along with its path structure into the virtual directory. Figure 30 illustrates the system deployment process.

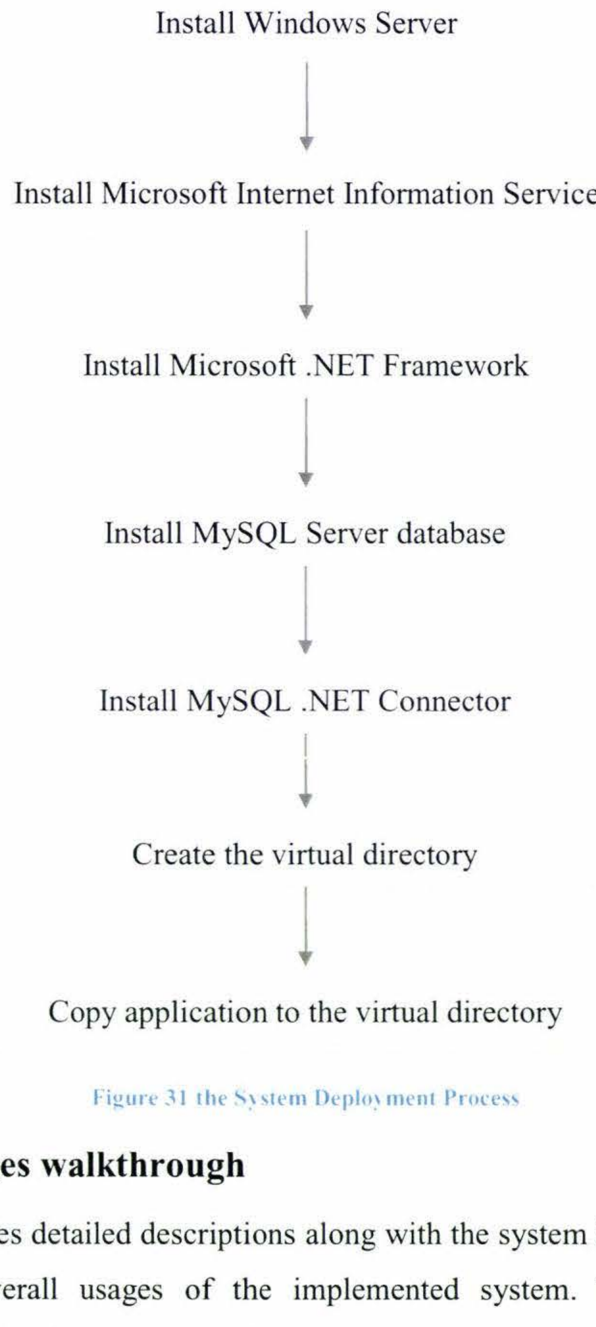

Figure 31 the System Deployment Process

5.3 System usages walkthrough

This section provides detailed descriptions along with the system interface screenshots to demonstrate overall usages of the implemented system. The system usages walkthrough is divided into four parts based on the implemented system components, which are "User Login and Registration", "Learning Content Selection", "Learning Style Identification", and "Selection Management". The system can also be accessed on the http://is-research.massey.ac.nz/~jian/.

5.3.1 User Login and Registration

The user authentication functionality is implemented for two purposes – multi-user support and system security.

When the user tries to use the system, a login page is presented (figure 31). The user needs to enter his/her user name and password to log in the system. If the login fails, the page will display a warning message to prompt the user to try again (Figure 32). If the user is new to this system, he/she will need to register for a user account. By clicking the "New User" button in the login page, the user will be redirected to the registration page (Figure 33). The user will then need to provide his/her user name, password, and real name to create a new account. If the user name that the user provides already exists in the system, a warning message will be displayed to ask the user to choose another user name (Figure 34). If the user tries to access any system resource without system authentication, the user will be redirected to a page with warning message indicating that the user is not authorized to view the requested contents (Figure 35).

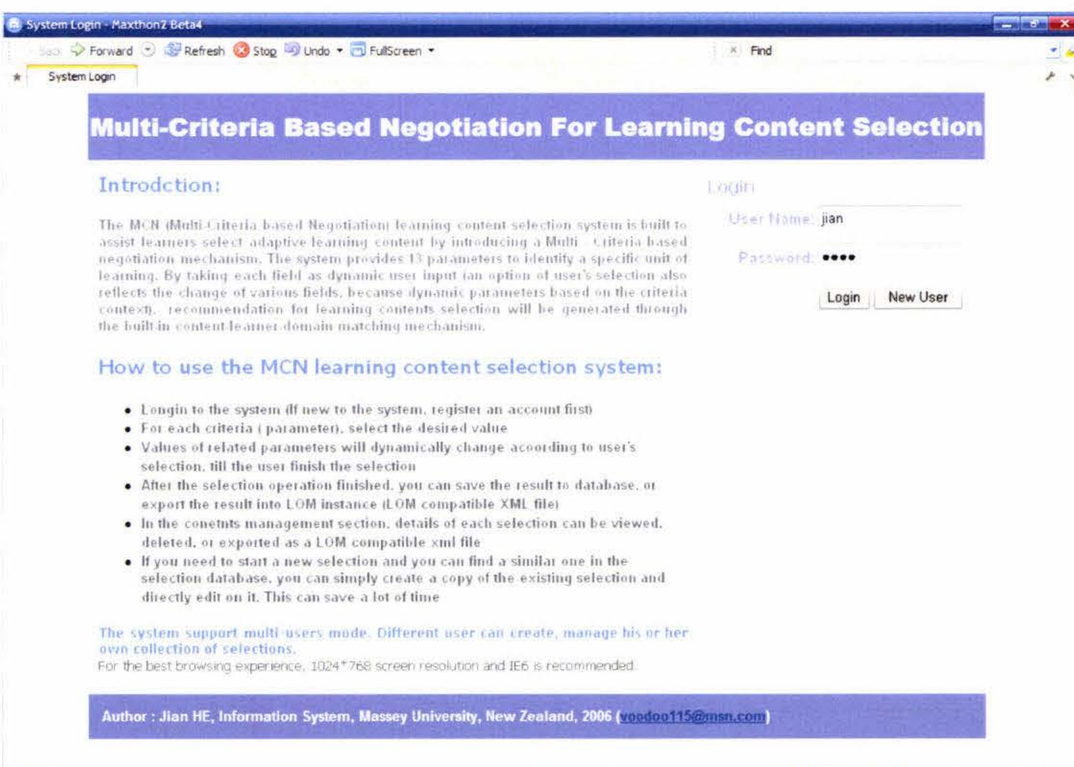

Figure 32 User Login

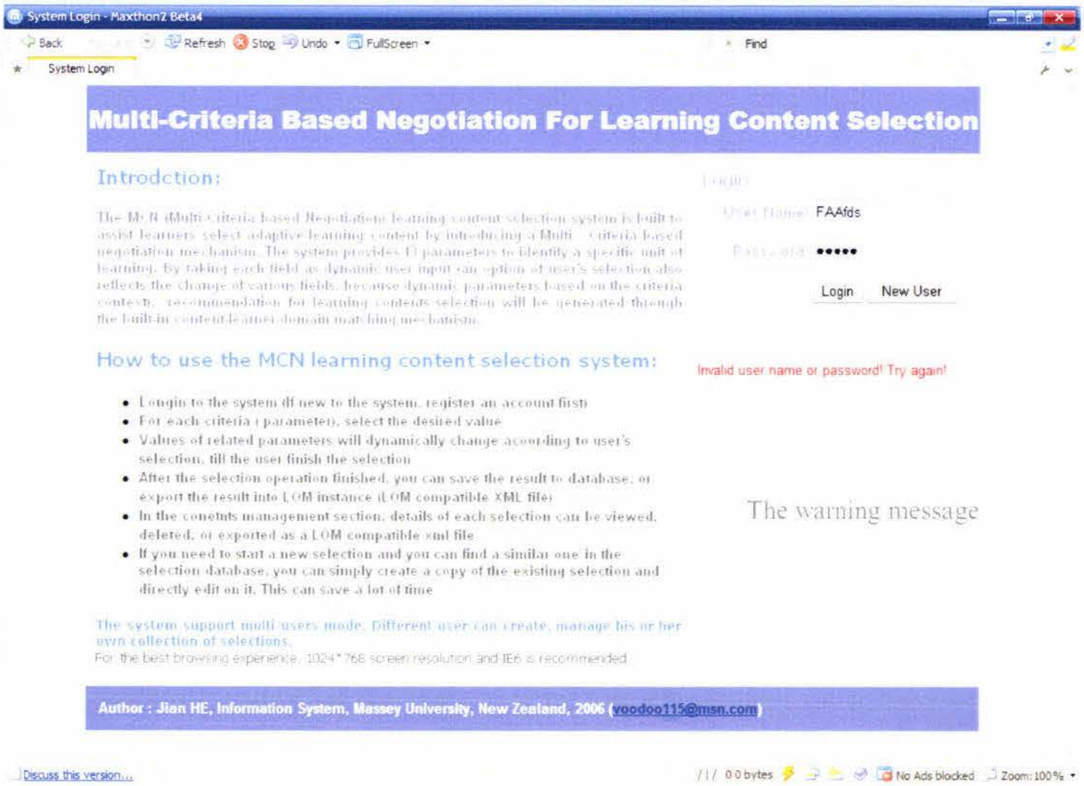

Figure 33 the Failed Login

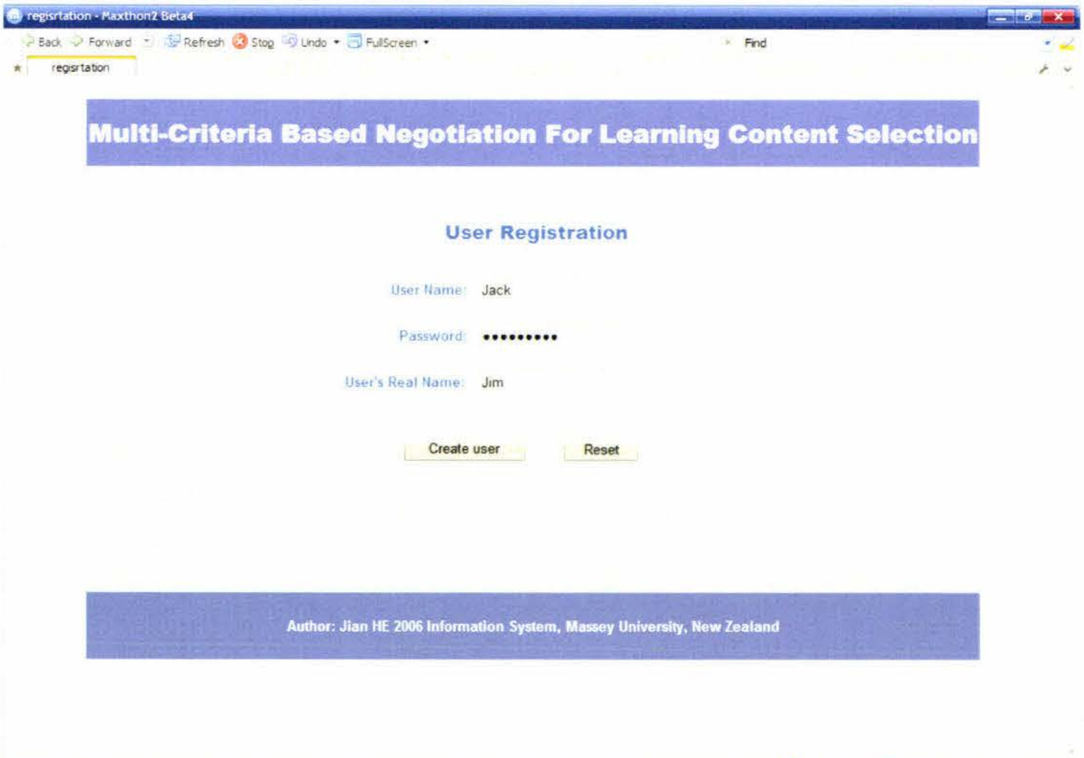

Figure 34 User Registration

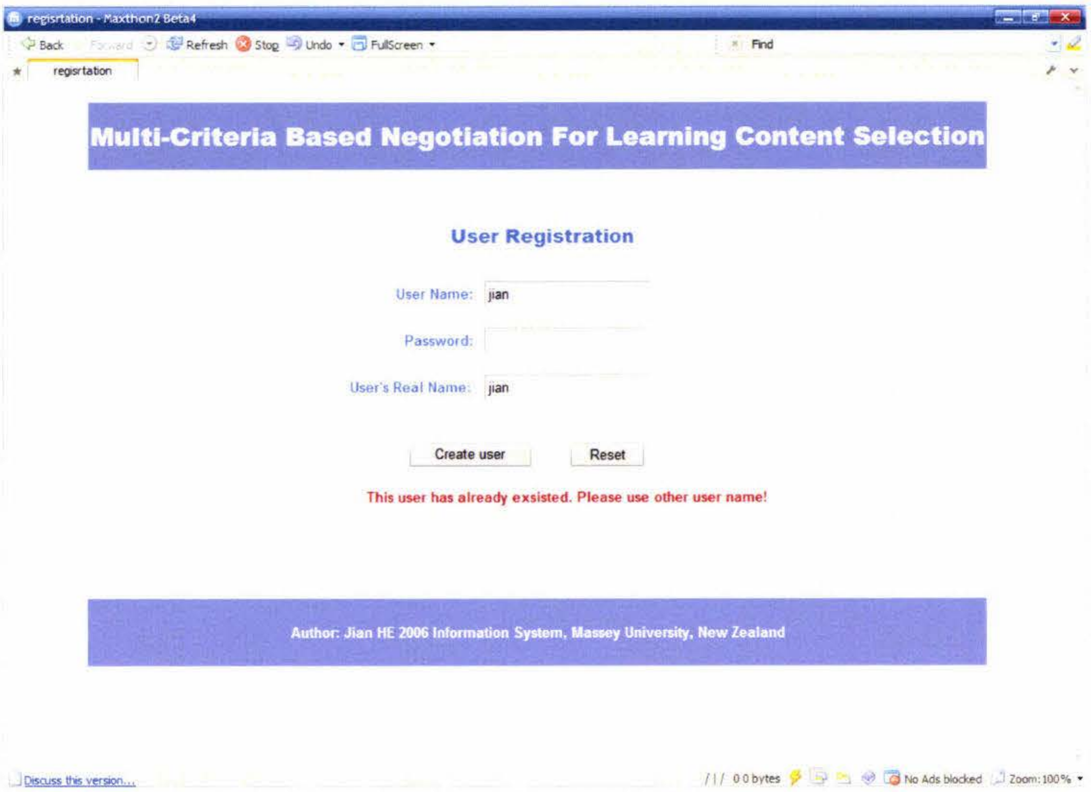

Figure 35 User Has Existed

Figure 36 the "Unauthorized" Warning Page

5.3.2 Learning Content Selection

After successful login, the user enters in the Content Selection page (Figure 36). Within this page, drop-down lists are used to represent the content selection parameters. User can select desired values from these parameters.

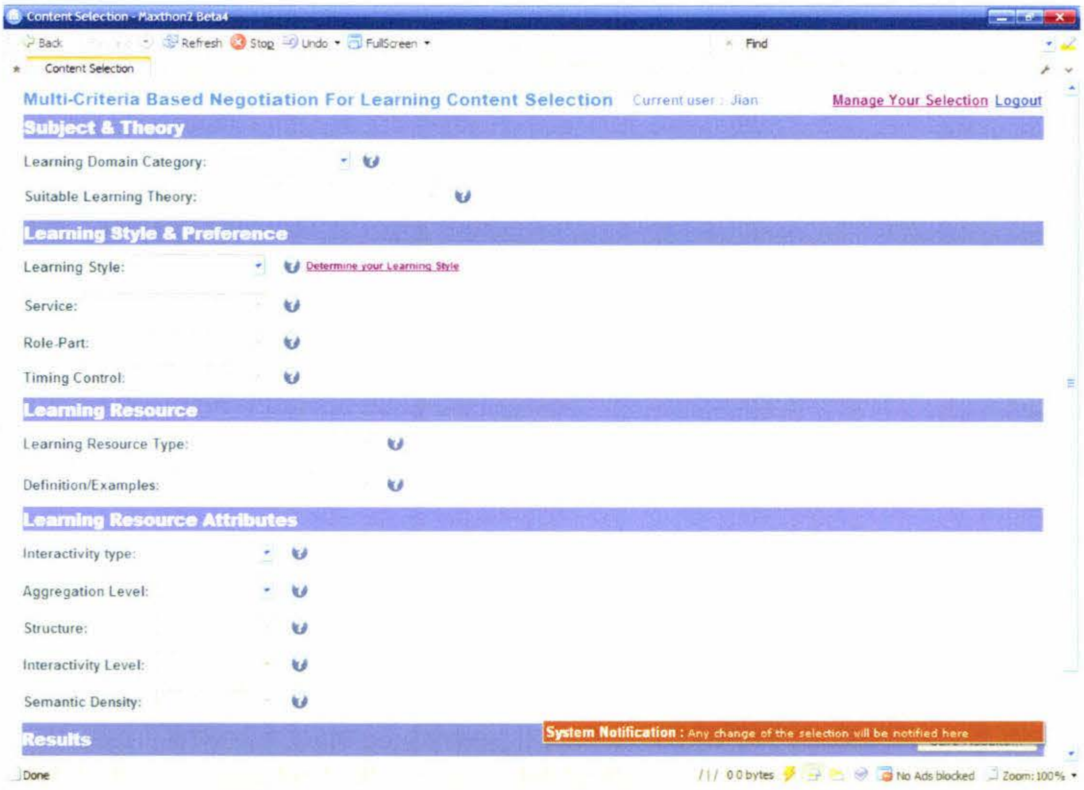

Figure 37 the Content Selection Page

According to the dependency rules, the parameters are correlated with each other. When the user is selecting values, relevant parameters will dynamically change their possible values. To reflect this dynamic process, the system provides early prompts to let the user know what changes might happen when the value of a certain parameter is selected. When the user hovers with the mouse over a parameter, a message prompt is displayed to tell the user which relevant parameters will be accordingly influenced and these influenced parameters blink in the red color (Figure 37). Furthermore, a floating bar in the right corner of the page provides notifications about what events will happen when a particular action is performed on this page.

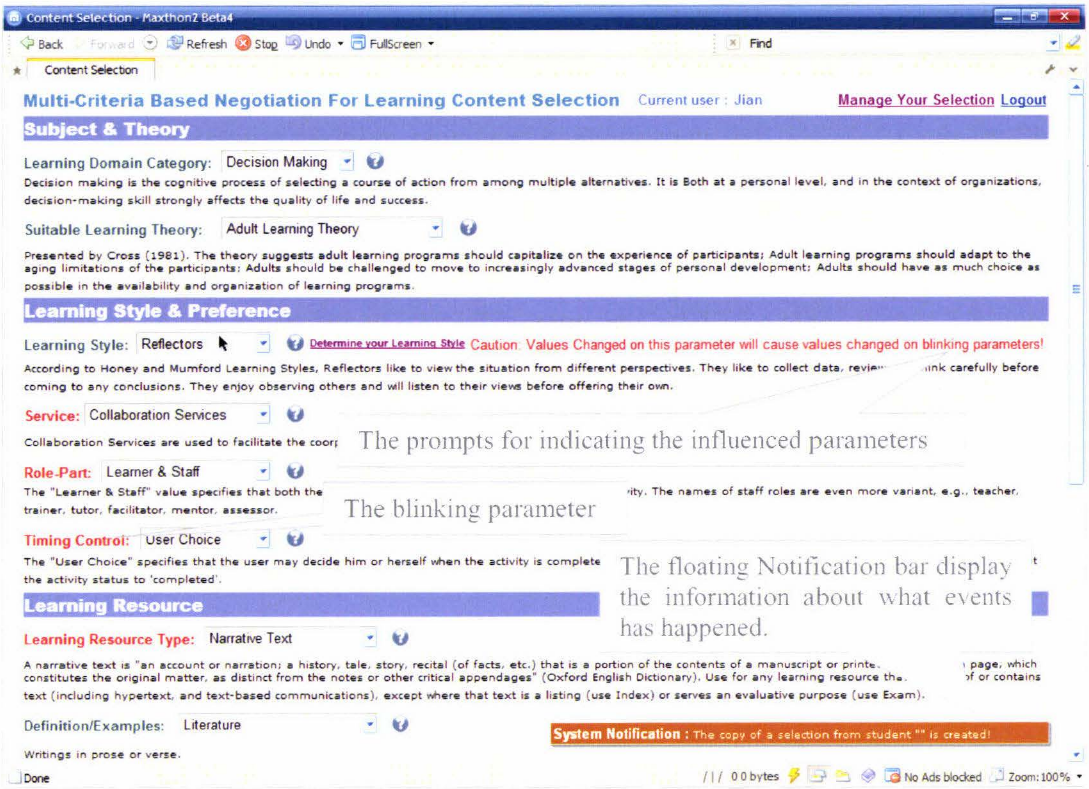

Figure 38 the Blinking Prompts for Correlated Parameters

When finishing the content selection, the user can save current selection context into the system database. After the user clicks the "Save Results" button (Figure 38), a save results dialog (Figure 39) is presented. In this dialog, the user needs to enter the learning topic that is associated with this content selection process, so that it can be used to distinguish the current saving selection from other selections stored in the database. Moreover, the dialog provides a summary of the currently selected values for each parameter, so as to give a chance to let the user re-check the selected values. After the user clicks the "Save to Database" button in the dialog, the selected values are finally saved into the system database. The user can also cancel this dialog and return to the selection page. In this case, no data is saved to the database. After the selection is saved, a redirecting dialog with three options is presented (Figure 40). By selecting one of the three options, the user can choose to start a new selection, continue the current selection, or manage his/her saved selections.

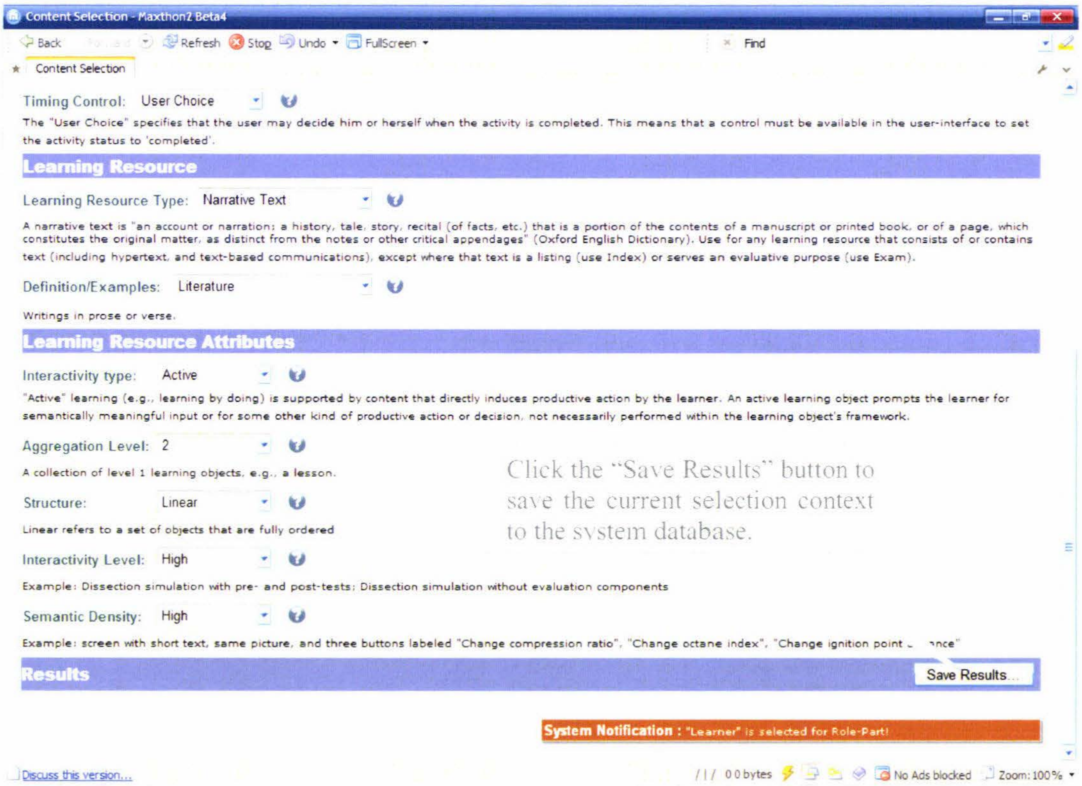

Figure 39 the Save Results Button

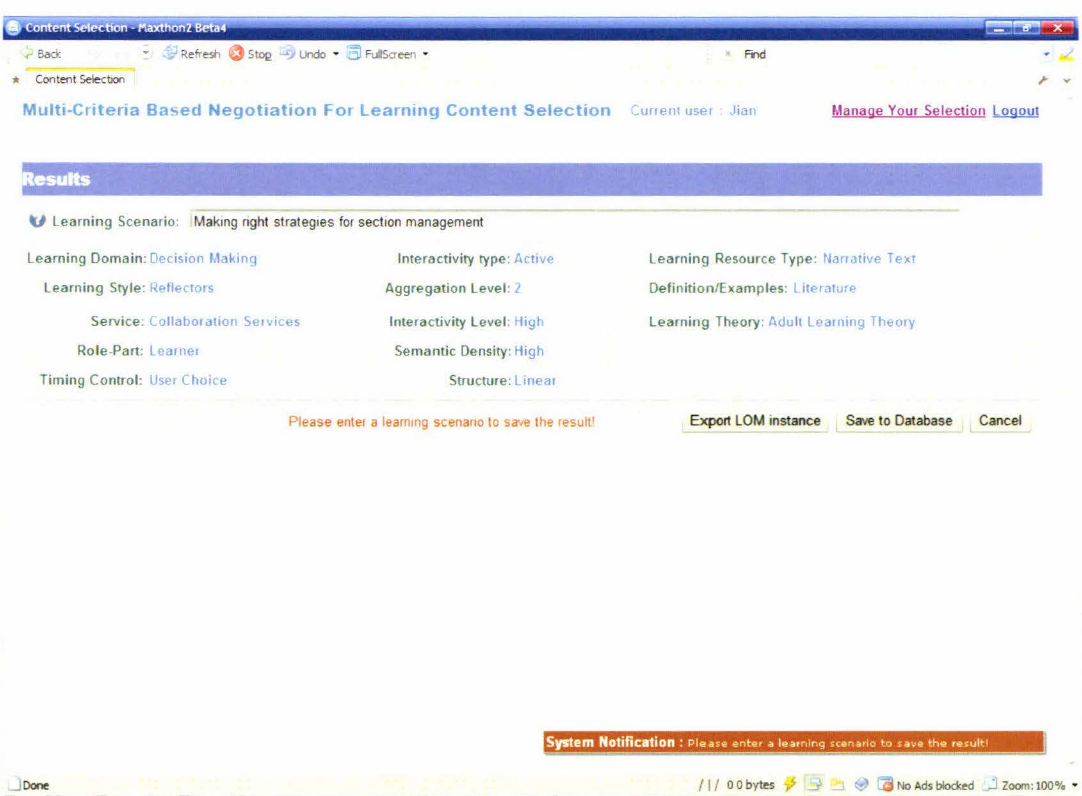

Figure 40 the Save Results Dialog

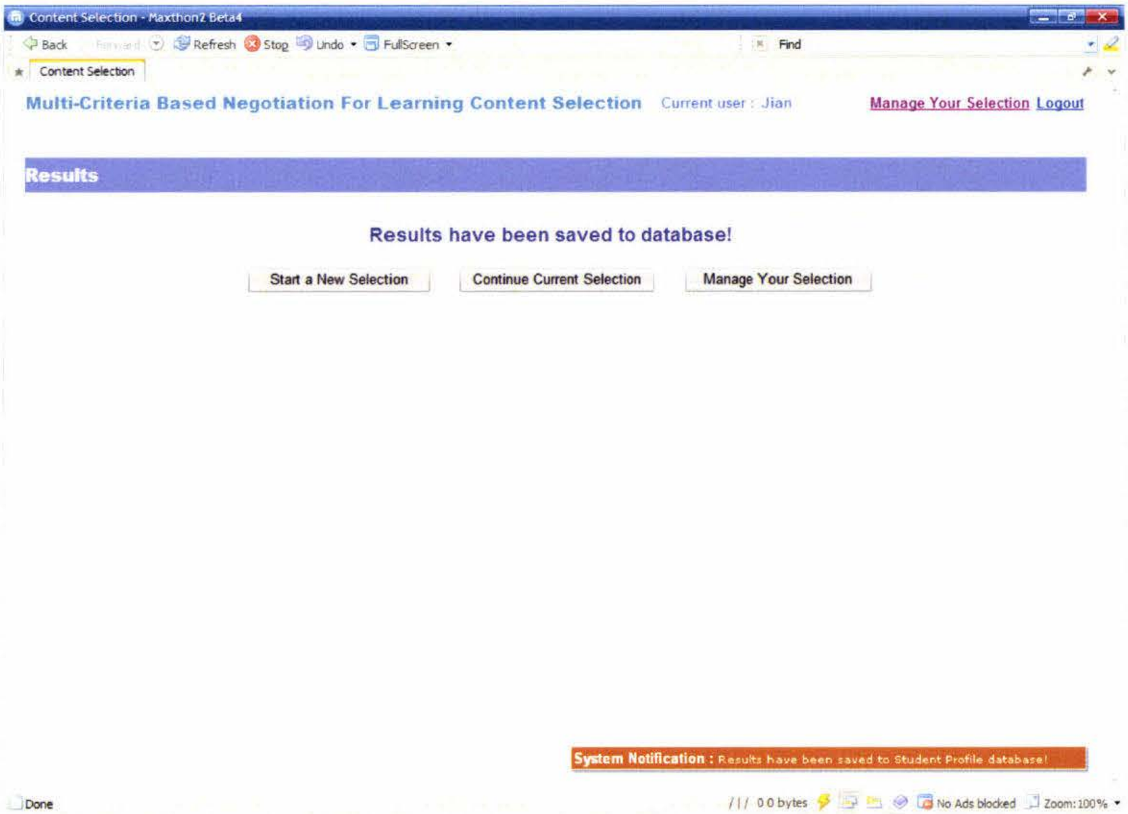

Figure 41 the Redirecting Dialog

As an important feature, comprehensive help information is implemented in the content selection page. Following each parameter value that the user selects, a general explanation is displayed (Figure 41) so that the user can have basic understanding about what the selected value means. In addition, for each parameter in the selection page, a brief introduction is popped-up when the user hovers with the mouse over the question mark icon following the parameter (Figure 41). Furthermore, a more detailed help is provided for each parameter. If the user clicks the question mark following a parameter, a pop-up window appears containing comprehensive explanations and the relevant dependency rules for that parameter are displayed (Figure 42). Thus, the user can have deeper knowledge about what content characteristic the parameter describes and what other parameters are associated with this one.

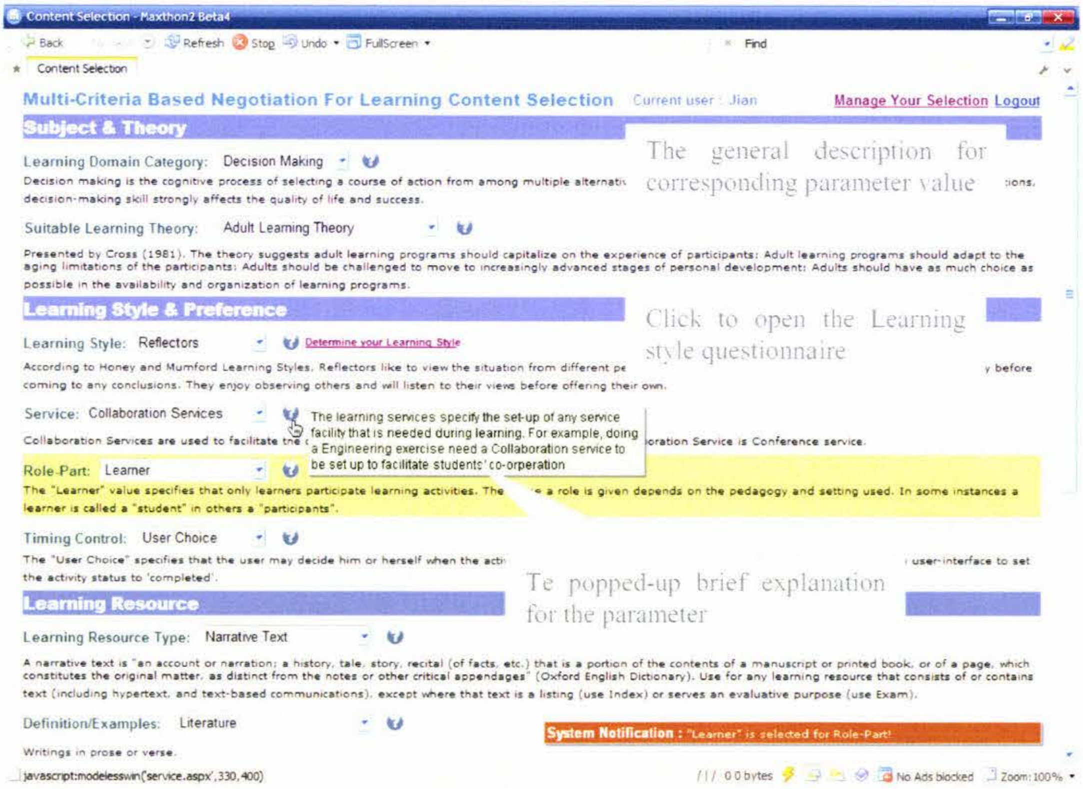

Figure 42 the Help Information for Parameters and Selected Values

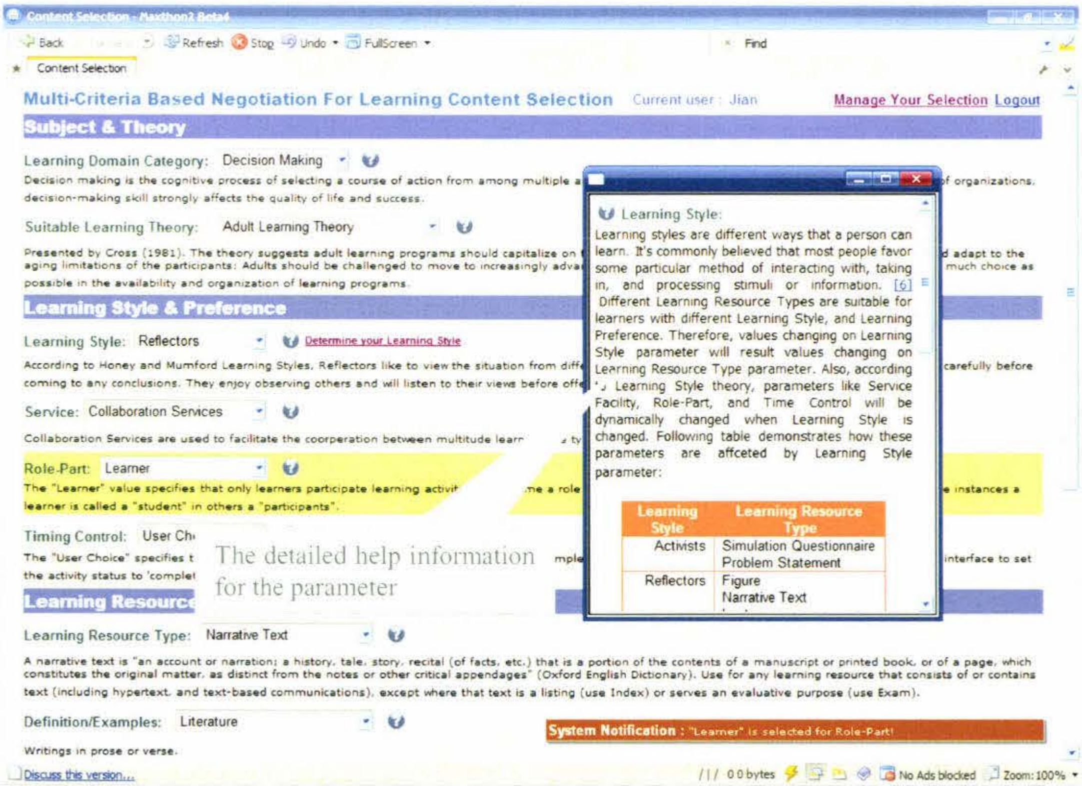

Figure 43 More Comprehensive Help for Parameters

5.3.3 Learning Style Identification

In the Content Selection page, when the user clicks the "Determine your Learning Style" link, the Learning Style Questionnaire page (Figure 43) is presented to the user. To use this questionnaire, the user honestly ticks the question statement with which the user agrees more then he/she disagree. After the finished questionnaire is submitted (Figure 44), the user preferences regarding the Honey & Mumford's four types of learning styles will be automatically generated based on those ticked questions (Figure 45). Therefore, the user can use the identified learning style as the values for the Learning Style parameter.

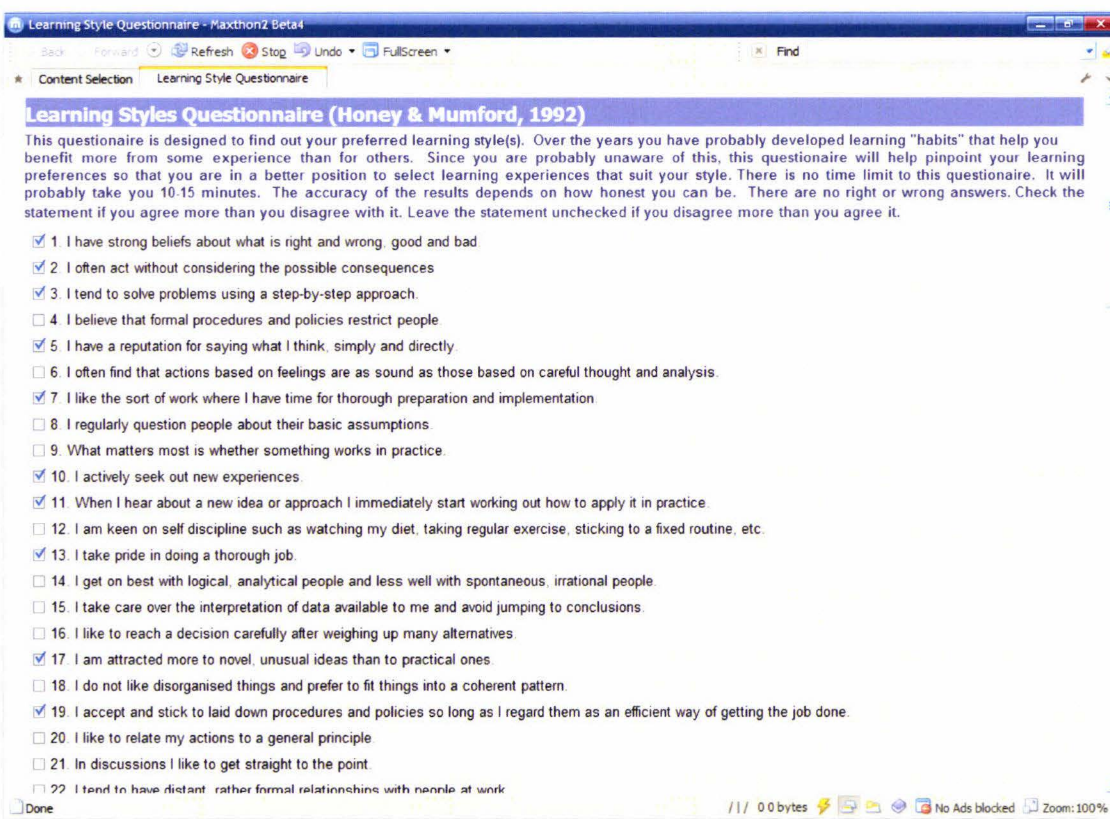

Figure 44 the Learning Style Questionnaire

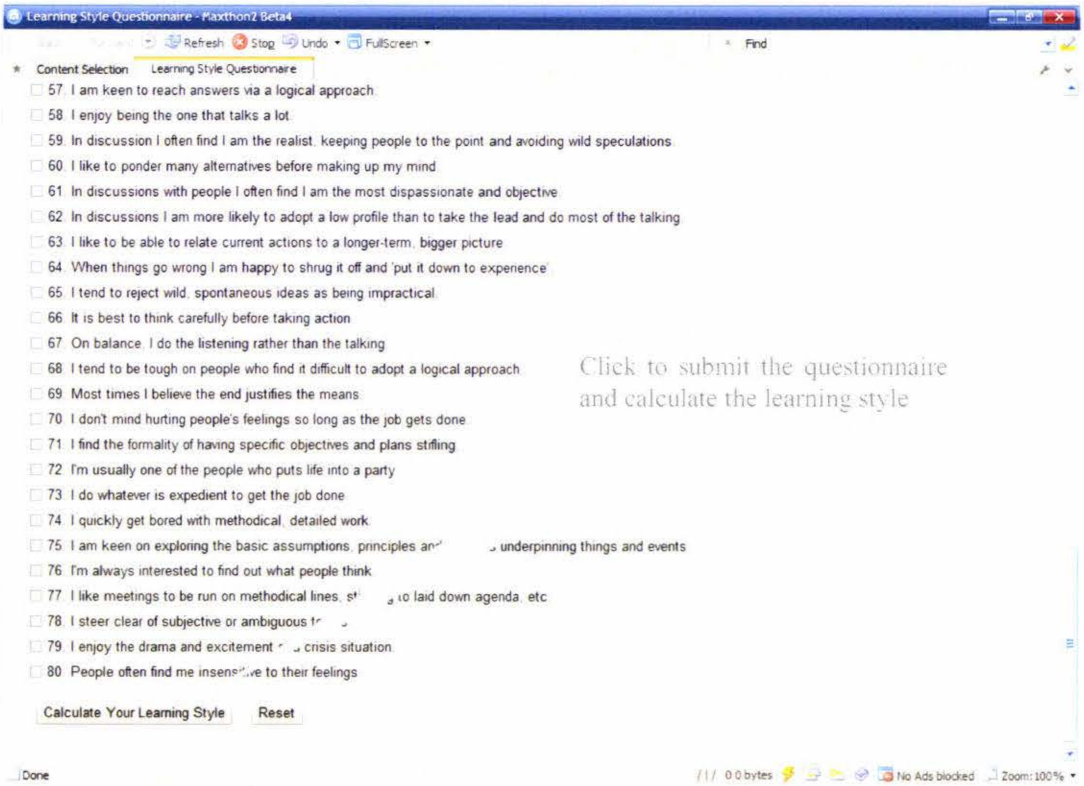

Figure 45 Submit the Questionnaire

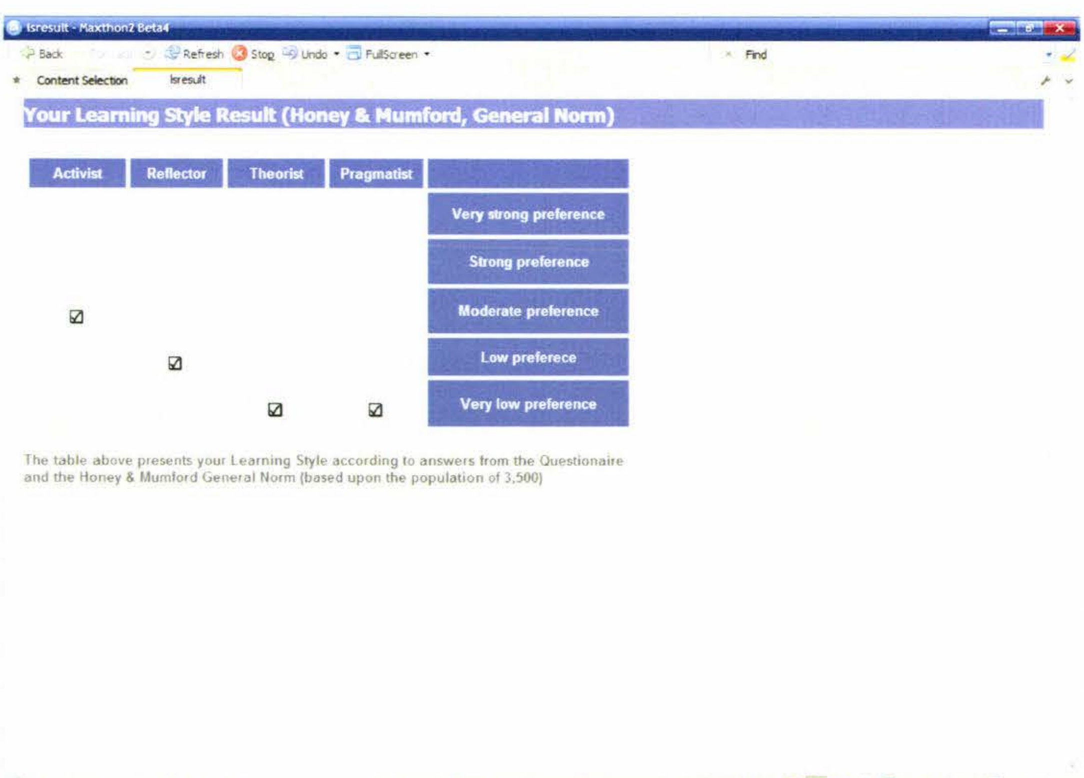

Figure 46 the Generated User Preference regarding Four Types of Learning Style

5.3.4 Selection Management

By clicking the "Manage your Selection" link on the up-right corner of the Content Selection page, the user is brought to the Selection Management page (Figure 46). In the Selection Management page, the user can browse the details of the selected record (Figure 47), delete the selected record (Figure 48), modify the selected records (Figure 49), and export the selected record to the LOM compatible XML file (Figure 50). To browse the record details, the user simply clicks the corresponding "Details" link of the selection record. To delete a record, the user can click the corresponding "Delete" link of the desired selection record and confirm the delete dialog. To modify a selection records, the user selects desired record and clicks the "Modify" button. Then, the parameter values in the selected records will be copied to the Content Selection page, and the user can do the modification job in the Content Selection page based on the imported copy. Finally, to export a record to the LOM instance XML file, the user selects a desired record and then, clicks the "Export LOM Instance". Afterwards, a file download dialog is presented for the user to download the generated XML to the user's computer. Figure 51 shows a generated LOM instance XML file.

Figure 47 the Selection Management Page

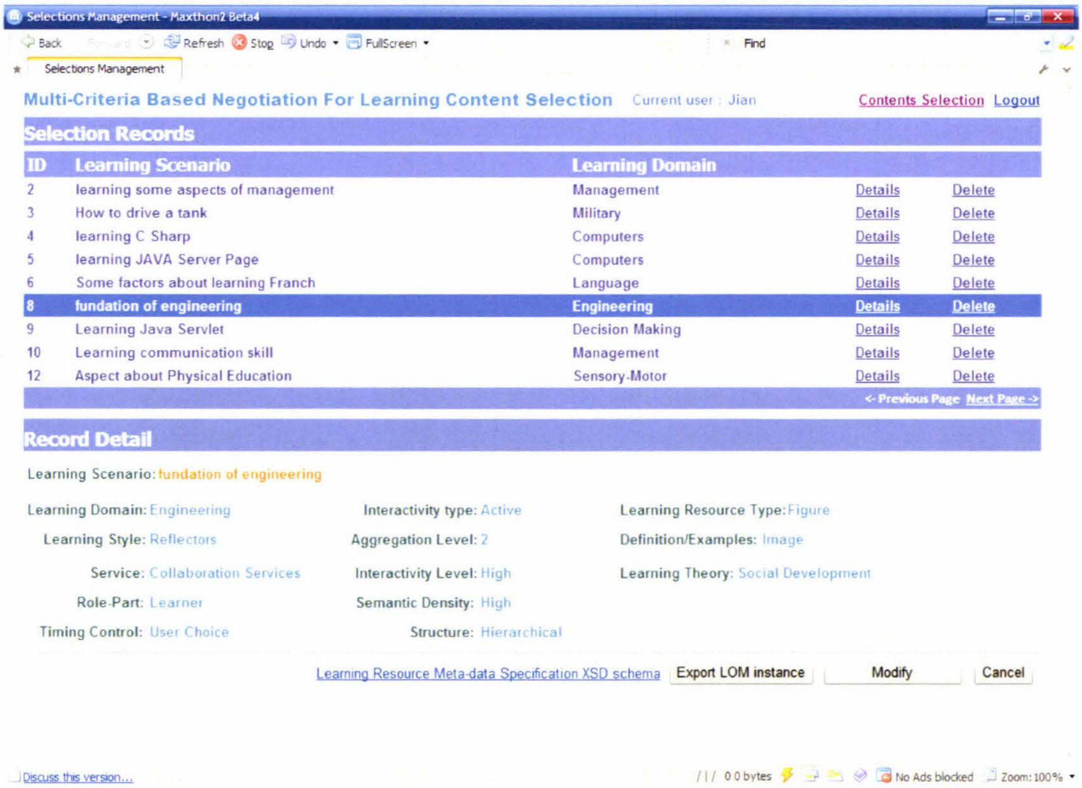

Figure 48 Browse a Selection Record

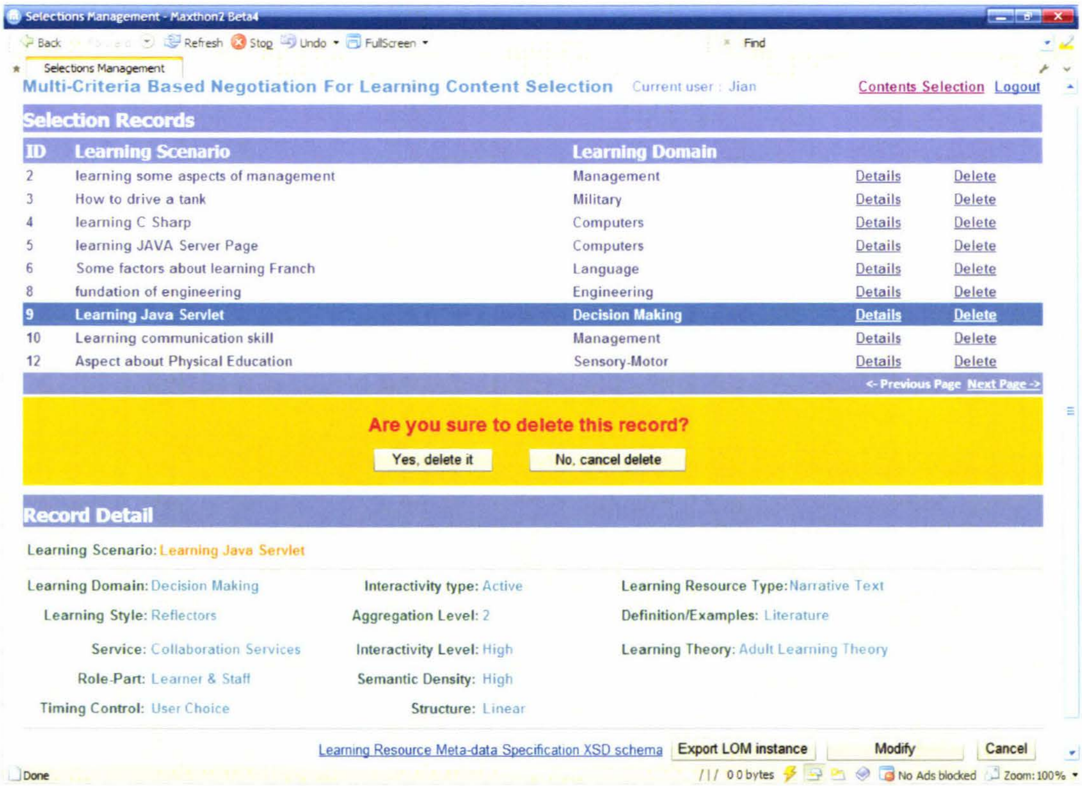

Figure 49 Delete a Selection Record

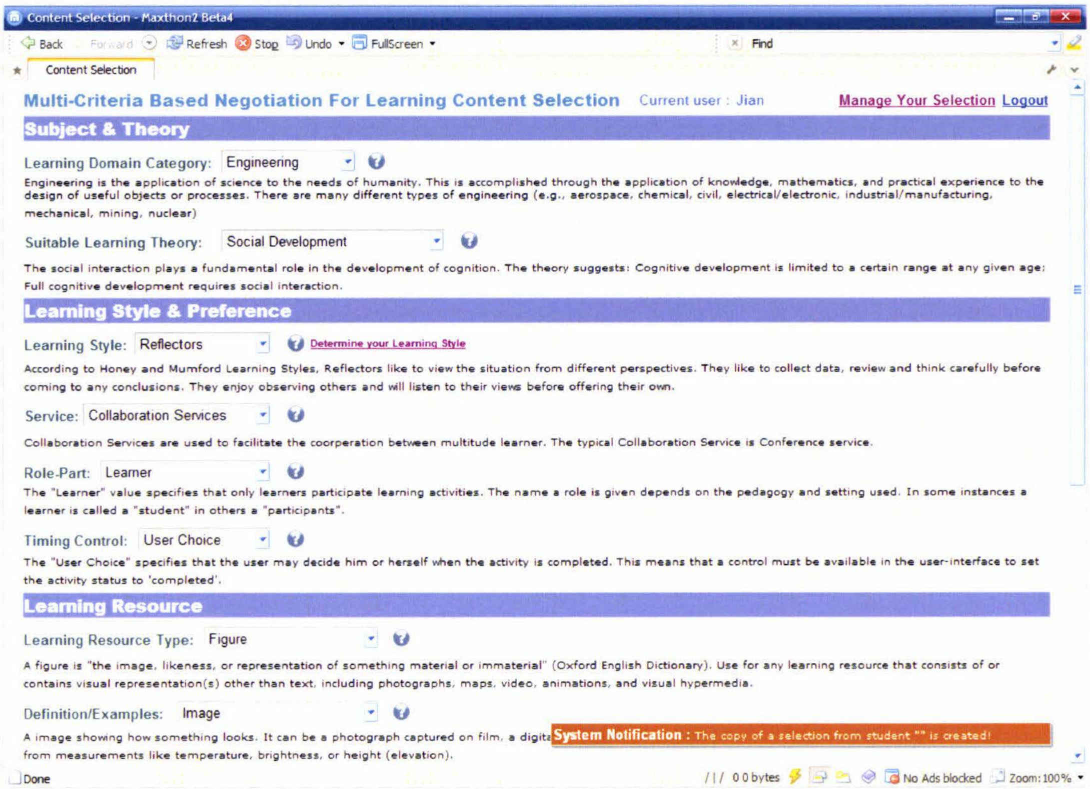

Figure 50 Parameter Values Copied to the Content Selection Page for the Modification

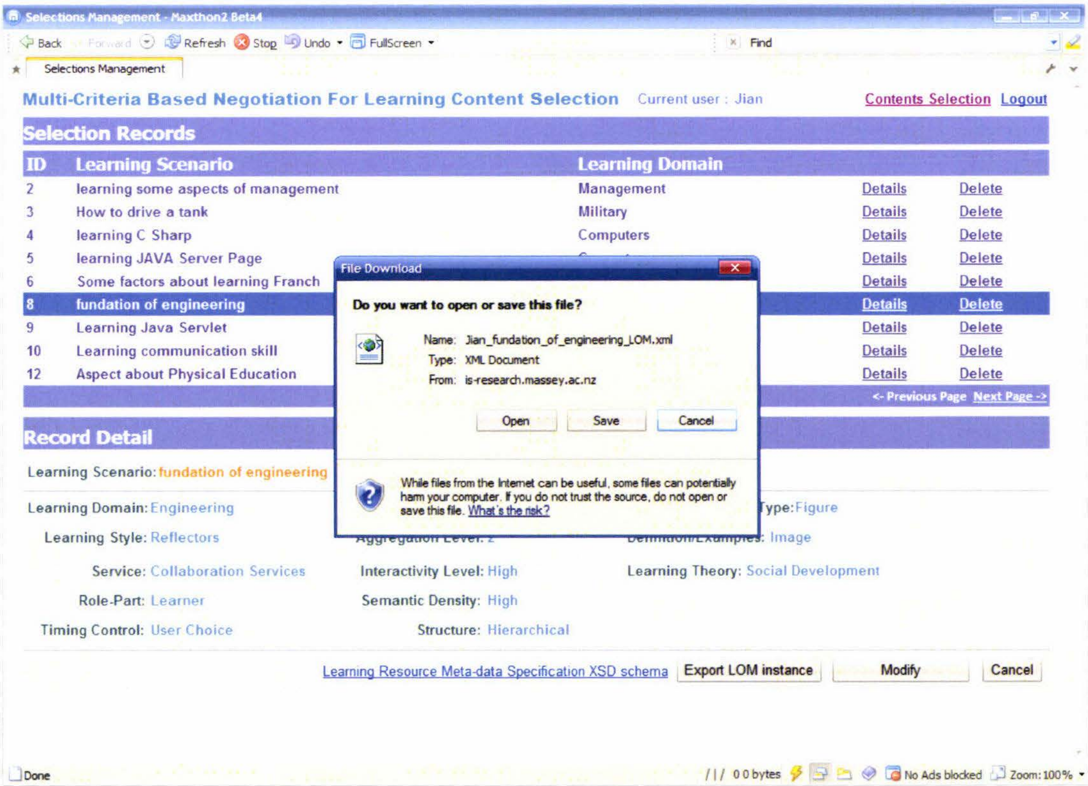

Figure 51 Export the LOM Instance XML File

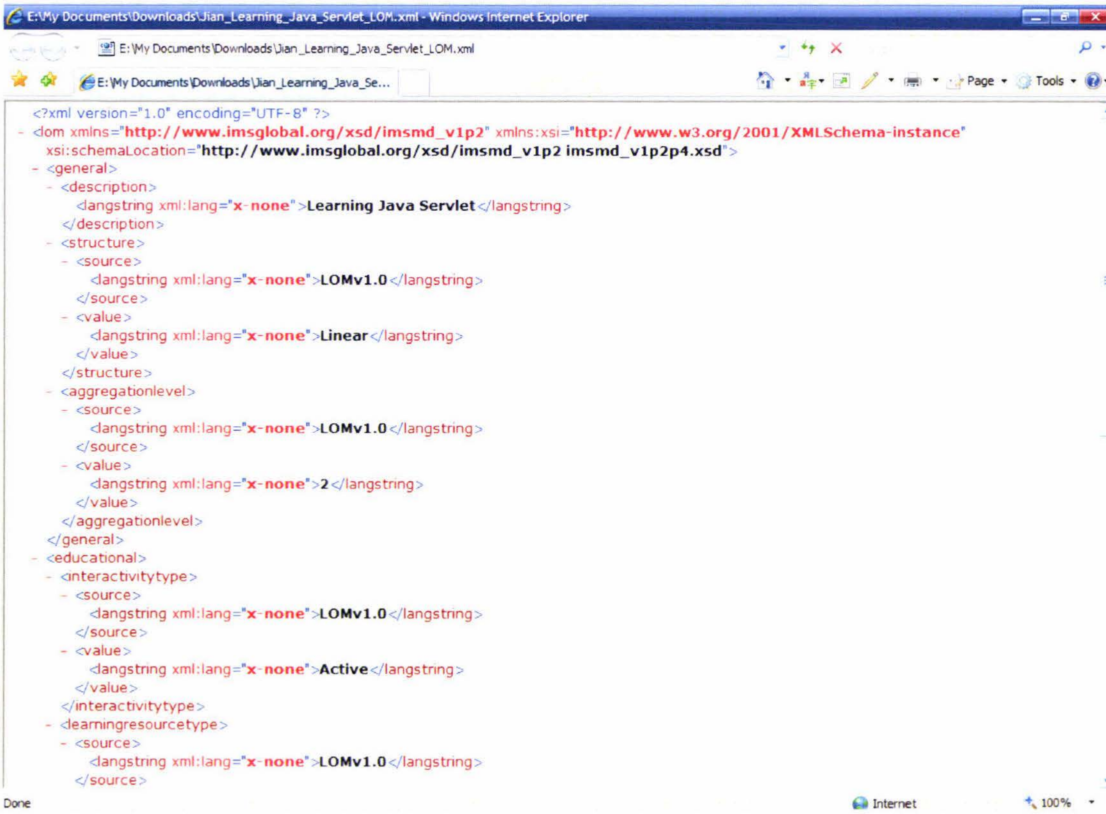

Figure 52 the Generated LOM Instance XML File

Summary

In this chapter, the running environment and the deployment process of the implemented system is elaborated. Due to the adoption of the Microsoft .NET Framework, the Windows based underlining server components are compulsory for successfully deploying the system. After that, a comprehensive system usage description is presented, providing a guideline for proper use of the system.

Chapter 6 System Evaluation

6.1 Introduction

In order to assess the effectiveness of the proposed content selection approach, we conduct an evaluation for the implemented system in this chapter. Firstly, we specify the general objective of the evaluation. Then, the evaluation participants and the evaluation method are introduced. After that, we present a summary to illustrate the questionnaire results, followed by the data analysis based on the results. Finally, the evaluation results are discussed.

6.2 Participants of the Evaluation

To test the prototype system, a total of 22 people participated in the system evaluation. These people include:

- Twelve undergraduate students;
- Eight postgraduate students;
- Two professional lecturers.

Due the diverse discipline that the proposed framework covers, it is difficult to develop testing tasks for every subject respectively. Hence, the evaluators are only assigned one task to perform, which is to freely use the functionalities of the system to choose learning content instead of working on the single test case tailored for each subject. In the evaluation, all participants were asked to use the system independently. After getting the experiences of the system, an evaluation questionnaire was provided for them to answer. The results of the content selection and the feedback of the evaluation questionnaires were summarized and analyzed in the following sections.

6.3 Evaluation Method

Basically, the essential objective behind the proposed solution is to facilitate the traditional human based learning content retrieving process by adaptively offering pedagogically sound recommendations for learning content selection. To achieve this goal, the prototype system is implemented to meet the fundamental requirements specified in the "Concept Design and Analysis" chapter. Therefore, the main objective of the system evaluation is focused on the assessment of how the implemented functionalities benefit the content selection process for learners.

For achieving the assessments stated above, we developed the evaluation questionnaire to obtain the feedbacks from users. The questionnaire contains ten questions covering both the functional and non-functional aspects of the implemented system. Each question offers fives options for the users to choose. The last three questions need the users to freely write down their opinions. Based on the users' feedbacks, analysis was conducted, and its results were discussed. Table 13 presents the rationales behind each developed question.

Table 13 the Rationales for the evaluation Questionnaire

1	**Have you ever experienced using Web-based educational system? If yes, how often?** Get an initial view of if candidates ever have any experiences of using Web-based educational system. This would be essential for evaluators to more properly use the system. If users have previous knowledge on using a web-based educational system, the misunderstanding and unfamiliarity towards this system can be largely avoided. Thus, more precise feedbacks can be provided.
2	**To what extend do you consider this multi-criteria based negotiation framework is suitable for selecting learning content?** This question was developed to exam if this multi-criteria based negotiation approach is an effective way to choose learning content in terms of its essence. Answers from evaluators could reflect whether this approach can be suitably adopted for content selection from user's diverse angles.
3	**Do you think the system's parameter dependencies are Logical?** The system was built largely based on number of dynamic parameters that inter-relates with each others. Many parameters dynamically change its value when their dependencies are changed. In this system, whether these parameter dependencies and relationships are logically designed is fatal. This question was developed to get opinions about the logicality of the parameter dependencies based on user's point of view.
4	**How do you consider the ease of use of the system?** This question tries to get opinions of how easy to use or learn to use the

system. Complex navigation, content layout, and language use will drive users frustrated to use the system. To the extreme, users will be overwhelmed, and system's original purpose will very likely fail, if the system is too difficult to use.

Do you consider the system's functionality is useful?

Basically, the proposed concept framework is reflected in the functionalities provided in the implemented system. The usefulness of the functionalities is the most important measurement of software's quality. It represents how
5 useful the functionalities are and how effective those functionalities can be used by users to achieve their objective, and it also directly reflects the value of a system. So, this question was designed to find out the overall usefulness of functionalities provided in the system based on evaluator's answers. Thus to reflectively test the design of the framework.

Do you consider the system reflects your preferred demands of learning content?

The question was developed to exam if the system generated learning
6 content fulfills users' demands, compared with user's own judge of their favorite learning content. According to user's feedback, more generated content accord with user's favorites, more effective the system could be and more effectiveness of the framework could be proven.

Does this system show enough evidence that it can be a good complement tool for students to select learning content?

The system's design goal is to provide an alternative approach to assist learners selecting learning content based on a negotiation context. All the
7 system generated learning content should be used as recommendations to help learner further determine what content they would finally use. This question was designed to measure overall quality of the system. Whether the system meet its original design goal could be evaluated according to answers to the question.

As a leaner, how would you like to use it to select learning content?

This question was designed to evaluate to what extend users consider the
8 reliability of the system. According to answers to the question, whether users are confident to use this system could be measured. More users trust the system, more reliable the system is.

What do you think the main functional problem does this system have?

Possibly, not all the system's functionalities work properly. Errors or
9 inappropriate design maybe still exist. Constant functionalities polishing and flaws removing still need to be carried out. The question was developed to identify any functional design problems from the user's perspective.

If you were required to give a suggestion to improve the system functionality, what would it be?

10 This question was developed to collect any useful advices from users to further explore the possible improvements of the system. As a matter of fact, users' suggestions are diverse and intuitive. The answers of this

question could be very helpful for functionality improvement and the system's future extension.

6.4 Evaluation Questionnaire Summary

This section presents the summaries for the answers of the evaluation questionnaire.

Q1: Have you ever experienced using Web-based educational system (for example, Web-CT etc.)? If yes, how often?

Never used	A few times a year	Once a month	Once a week	everyday
1	4	15	2	0

Based on the question results, we can see that almost all participants have the experience of using web-based educational software. Besides, 15 people use web-based tools at least once a month. This number accounts for 68% of the total numbers of the participants. Therefore, the result indicates that the participants have relatively high frequency of using web-based educational system.

Q2: To what extend do you consider this multi-criteria based negotiation framework is suitable for selecting learning content?

Not suitable at all	Somewhat suitable	Suitable	Very suitable	No option
2	9	7	0	4

According to the question results, people think the proposed framework is suitable (7 participants) and somewhat suitable (9 participants) for learning content selection together account for 72% of the total participants. This result indicates that the proposed multi-criteria approach is accepted by most participants as a suitable solution for learning content selection.

Q3: Do you think the system's parameter dependencies are Logical? If not, why?

Disordered	Somewhat logical	Logical	Very logical	No option
0	7	6	0	9

For this question, all together 13 participants think that the parameter dependencies are logical. This number accounts for 59% of the total numbers of the participants.

However, there are significant 9 people that did not give their opinions. According to their answers, the most reasons for not giving choice are because they don't know for sure if the criteria dependencies are correctly mapped without seeing the rationales behind.

Q4: How do you consider the ease of use of the system?

Very hard to use	Hard to use	Easy to use	Very easy to use	No option
0	2	15	4	1

Based on the question results, we can see that most participants felt the system is easy to use. The numbers of positive answers account for 86% of the total numbers of the participants. The reasons for the negative answers are some explanations for the parameters and values are not clear, and some parameters only offer few values for the user to select.

Q5: Do you consider the system's functionality is useful? Why?

Useless	Somewhat useful	Useful	Very useful	No option
0	8	10	2	2

As the question results show, nearly all participants consider that the system's functionality is useful. The reasons include:

- The parameter values can be automatically adjusted to reduce the values searching time.
- The system provides useful explanations for each criteria and values.
- The useful prompts are provided to the user to foresee the influences on related parameters.
- The selection results can be easily managed.
- The individual's learning style can be measured by filling the questionnaire provided by the system.

Q6: Do you consider the system reflects your preferred demands of learning content? If not, why?

Strongly Disagree	Disagree	Agree	Strongly agree	No option
0	3	13	1	5

Based on the question results, we can see that more than half of the total participants (63%) agree that the prototype system reflects their preferred demands of learning content. Three participants think the generated options do not match their preferences of learning content selection. Five participants did not present their opinions. According to the answers from these six participants, they chose to reserve their answers because they do not know for sure which learning content they actually prefer or their preferences of content selection vary all the time.

Q7: Does this system show enough evidence that it can be a good complement tool for students to select learning content?

Strongly Disagree	Disagree	Agree	Strongly agree	No option
0	2	17	0	3

Based on the question results, we can find that, although we have two participants disagree and three participants present no opinion, seventeen participants (77%) agree that the proposed system is a good complement tool for students to select learning content. This indicates that most participants considered that the system can be a good complement tool for helping them to select learning content.

Q8: As a learner, how would you like to use it to select learning content?

I will not use it at all	Use it as a complement	Use it as a reference	Use it and fully depend on it	No option
3	15	3	0	1

As the question results show, except three participants will not use the system, all together eighteen participants (81%) would like to use the prototype system to select learning content. Especially, fifteen participants would like to use the system as a complement tool. Only three participants will use the system as a reference. No participant will fully depend on the system when they are selecting learning content.

Q9: What do you think the main functional problem does this system have?

Based on the question feedbacks, the participants proposed three main problems.

- Some descriptions and explanations for the parameters or values are not expressive enough. This will probably make the user misunderstand the exact meanings of the parameters or values.
- Every time when the user performs a selection, the whole page will be refreshed. This makes the operations within the page inconsistent.
- It does not provide sufficient examples to account for the differences between the different *interactivity levels*.
- It seems like not necessary to require the user's real name for the user account registration.

Q10: If you were required to give a suggestion to improve the system functionality, what would it be?

According to the question results, following suggestions are proposed by the participants.

- Use more expressive and straightforward words to describe or explain the parameters and values, so as to avoid misunderstandings.
- Brief descriptions could be included for each parameter details in the selection management page.
- A tool could be developed to search learning objects based on the generated result.
- The floating System Notification should provide more detailed information.
- The system GUI should include more graphics.
- More detailed descriptions should be provided for the parameters.

6.5 Evaluation Discussion

According to the answers of the evaluation questionnaire, most participants have relevant experiences on using a web-based educational system. This positive result ensures that the participants have previous knowledge on using web-based educational software, so that the misunderstanding and unfamiliarity towards such a system can be considerably avoided and the relatively precise feedbacks can be provided in the rest questions.

The evaluation results suggest that the proposed multi-criteria approach is well accepted as a suitable solution for learning content selection by 72% of the total participants. The evaluation results also indicate most participants (81%) considered that the system is easy to use. Although nine participants did not give their opinion, more than half of the participants agreed that the framework provides logical parameter correlations. In addition, the functionalities of the system are proved to be useful according to the advantages specified by the participants. Most importantly, except those participants who are not sure about their preferred learning content, 63% of the total participants considered that the system reflects their preferred demands of learning content. Lastly, the test results show that, 77% of the participants thought the system is a good complement tool for content selection, and 81% of the total participants would like to use the system in the real content selection process. Based on the question results, we can conclude that the overall feedbacks from the evaluators appear to be positive. These positive evaluation feedbacks indicate that the proposed system functionalities are successfully implemented and the system's design goals are achieved on the whole.

Moreover, we received a lot very helpful suggestions from the evaluation participants for improving the system's functionalities. Within these suggestions, some can be quickly implemented with a little effort, such as improving the expressiveness of the descriptions, including more graphics, and so on. However, some improvements will involve considerable modifications on the current system. For example, if we need to avoid the page refreshment after each operation, more advanced technologies such as

AJAX (Asynchronous JavaScript and XML), ATLAS (Microsoft's implementation for AJAX) need to be implemented in order to only refresh the particular parts of a web page.

Furthermore, based on the evaluation result, we found that many students had difficulties to understand the meaning of some subjects due their lack of prior knowledge of the terminologies and pedagogical thinking behind these subjects. Therefore, we consider that, the better effectiveness and performance could be achieved if students use the tool with assistance of an instructional designer or someone that familiar with pedagogical background.

Chapter 7 Conclusion

7.1 Introduction

In this chapter, we summarize the findings for this research. Firstly, we discuss the advantages of the proposed multi-criteria mechanism for learning content selection. After that, the system's limitations caused by the adoption of the educational metadata standards are addressed and the solutions are proposed. Finally, we propose possible future works for improving the existing system.

7.2 Discussion

7.2.1 Advantages and Contributions

In this research, the proposed solution is designed and implemented to facilitate the traditional human based learning content retrieving process. By interacting with thirteen identified criteria that describe the unit of a learning content, the learner is offered with pedagogically sound recommendations for learning resources selection. The final generated parameter context can be used as learning content searching criteria to reduce the searching space when acquiring learning content online. Based on the positive evaluation results, the implemented system is considered to be an effective tool for helping learners to select suitable learning content that suit their needs. The dynamic multi-criteria mechanism is proposed and successfully implemented. Within the proposed mechanism, parameters deriving from various educational metadata standards are identified and adopted to describe the learning content selection process. Correlations between the identified parameters are addressed and are built into dependency rules based on diverse instructional theories. Compared to early content selection approaches, which are lack of pedagogy supports, the proposed multi-criteria approach has two key advantages:

- *Accredited Criteria*: The parameters used for content selection are derived from various standardized educational metadata, which ensure the adopted variants are highly authoritative in comparison with the criteria based on developers' own understanding. Thus the reliability of the system is guaranteed.

- *Realistic Correlations*: Based on the classic pedagogical theories, the parameters' correlations are set up, so as to introduce the adaptivity into the system and apply an emulation of human decisions making for the content selection process.

In addition to the proposed mechanism, the prototype system offers several other benefits for the content selection process. The prototype system is implemented as a distributed three tiers web application, which provides an easy access for the users based on various locations. By taking advantages of the .NET technologies, a highly interactive user interface is provided for the user to dynamically select suitable learning content in a foreseeable way. Furthermore, by embedding the parameters and the dependency rules in the database, a scalable basis is provided for the future extension.

7.2.2 Limitations and Solutions

In this research, we convert existing elements in various educational metadata standards into content selection parameters. The adoption of this converting approach is mainly due to the accredited nature of the metadata standards. The educational metadata standards are produced by 'accredited' organizations. It is highly authoritative, and guarantees an open, fair, transparent and inclusive process. However, even these standardized educational metadata represent the most advanced development in terms of e-learning technologies, they still have several limitations and shortcomings. Recent investigations (Ingrid & Baumgartner, 2003; Fraunhofer IAO 2003) show that these limitations are mainly raised on the definitions of the controlled vocabularies for elements. For example, Schulmeister (2003) complained that, the vocabulary definition of the *interactivity* element (5-step scale from *very low* to *very high*) is meaningless and of no practical help to the developers of learning systems and script writers, since a high or low level of interactivity can refer to very different forms of a user's freedom of action or behavior. This very loose definition makes it very difficult to set comparable standards. Ingrid & Baumgartner (2003) also pointed out that, the vocabulary definition of the learning *resource type element* is somewhat ambiguous. It mixes different media types (e.g. text, slide) with different representation of content (e.g. graph, table, narrative text) and different educational interaction pattern (e.g. simulation, experiment, and lecture). Neither are these subcategories complete (e.g. there is no media type of sound, movie) nor are the semantic borders between different vocabularies well defined (e.g. what is the difference between a diagram, a figure or a graph?). Therefore, the limitations originated from the very definitions of the educational metadata standards will implicitly cause the functional weaknesses of the proposed multi-criteria based content selection system due to the adoption of the standards.

To solve this problem, current research proposes self-developed or customized vocabularies. However, this approach breaks the original intentions of the standardization. If the interoperability and the credibility can not be achieved, why bother standards? So, based on this thought, we consider that the constant perfecting and refinement of the standard definitions is currently still the most possible solution for improving the expressiveness of the criteria.

7.3 Future Works

According the results of the system evaluation, many suggestions for improving the functionalities of the system are proposed by the evaluation participants. Therefore, the future works of this research should be focused on the further improvement of the system's functionalities based on the evaluator's advices. In addition, some other important extensions could also be developed.

7.3.1 Searching for More Criteria

So far, for the proposed learning content selection system, we have identified thirteen parameters that are derived from various standardized educational metadata to describe the "unit of a learning content". As indicated in the system evaluation, the multiple dynamic criteria offer an effective way for learners to select the learning content that suit their needs. However, it is very likely that we did not turn all possible relevant elements in the standards into appropriate parameters for the system. Many other elements in the IEEE LOM, IMS LD, and IMS LIP are not included as the system parameters. This is mainly because the supporting literature is not available or unclear to address the correlations for those elements. For example, the elements such as Difficulty, Context, and Typical Age Range in the LOM specification might have the potentials to be turned into parameters. However, we currently could not find suitable literature to support that. Hence, how these elements can contribute pedagogical hints for the content selection remains unsure. Moreover, the educational metadata standards are still under evolution. It is also very possible that new elements will be added to the specifications, and new correlations will be defined. Therefore, the future works for the system should be focused on searching for more potential criteria for the system, so as to ensure the adopted parameters can cover various aspects of the learning content selection as much as possible.

7.3.4 Extension Tools for Instructional Designers

As discussed in previous section, new criteria and dependency rules might be added in the system. This might raise a system maintenance difficulty. It is very time consuming to manually edit the application source code to embed new parameters and the criteria dependency rules. Therefore, the future improvement of the system should also include the development of an extension tool with which the teacher can use to conveniently add new parameters and build dependency rules. Moreover, the parameters and the criteria dependency rules are built in the system database. This offers a convenient implementation basis for developing applications to manage parameter and dependency rules stored in the database.

7.3.3 Multi Learning Style Criteria Support

For identifying the user's learning style, the Honey & Mumford's learning style theory is adopted in our proposed system due to its wide commercial application. Nevertheless, according the discussion in the literature review, no one learning style theory is supposed to be better than the others. All theories are considered to be possible to measure an individual's learning style and preferences according to their particular instruments. Therefore, we can further improve the learning style identification process by introducing more than one learning style theories. For example, the Honey & Mumford learning style theory measure the learner's learning preferences based on human experience. As an option, we can introduce another learning style theory, say Fleming's *VAK Framework,* which measures learning styles based on learners' physical preferences (Vision, Auditory, and Kinesthetic). By this means, the learner's learning style can be determined based on various learning style theories. Therefore, the identification of the learner's learning style could be more objective rather than only depending on a single theory.

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Appendix A

Examples of Learning Resource Types

Southern Regional Education Board (2005), SCORM Users' Guide to Learning Object Metadata (LOM)

Resource Type	Examples
Exam	**Alternative assessment** **Authentic assessment** **Curriculum-based assessment**: Direct and frequent measurement of student performance on the classroom curriculum in order to ascertain student instructional needs. Used principally for instructional decision-making, the approach also supports screening, placement and monitoring in special education. **Informal assessment:** Appraisal of an individual's or group's status or growth by means other than standardized instruments. **Observation-directed:** Intentional examination of persons, situations or things to obtain information. It includes the quantified values by which observed facts are represented. **Peer evaluation:** Evaluation by one's peers. **Portfolio assessment:** Systematic collection of a student's work samples, records of observation, test results, etc., over a period of time for the purpose of evaluating student growth and achievement; used occasionally with populations other than students. **Self-assessment** **Self-evaluation:** Assessment of an institution, organization, program, etc., by its members or sponsors. **Standardized testing:** Tests for which content has been selected and checked empirically, norms have been established, uniform methods of administering have been developed, and which may be scored with a relatively high degree of objectivity. **Testing:** Gathering and processing information about individuals' abilities, skills, understanding or knowledge under controlled conditions.
Exercise	**Course:** A sequence of instructional units, often a semester long, designed by a teacher (or a faculty or other group of teachers) to advance significantly student skills, knowledge and habits of mind in a particular discipline and to help students meet specified requirements (as set forth in curricula or district or state policy). **Curriculum:** Academic standards — the knowledge, skills and habits of mind students are expected to acquire in particular grade levels (or clusters of grade levels) — and the units of instruction, often with sample lesson plans, illustrative student activities, and essential and supplementary resources that can help students reach those standards. It is often designed at the state or school district level by a team of teachers, curriculum specialists and other experts. **Educator's guide:** A guide intended for use by educators as a supplement to a lesson or unit plan. **Event:** A none-persistent, time-based occurrence. **Experiment** **Interactive resource** **Lesson plan:** A plan for helping students learn a particular set of skills, knowledge or habits of mind. It often includes student activities as well as teaching ideas, instructional materials and other resources. It is shorter in

22. I tend to have distant, rather formal relationships with people at work.
23. I thrive on the challenge of tackling something new and different.
24. I enjoy fun-loving, spontaneous people.
25. I pay meticulous attention to detail before coming to a conclusion.
26. I find it difficult to produce ideas on impulse.
27. I believe in coming to the point immediately.
28. I am careful not to jump to conclusions too quickly.
29. I prefer to have as many sources of information as possible. The more data to think over the better.
30. Flippant people who do not take things seriously enough usually irritate me.
31. I listen to other people's points of view before putting my own forward.
32. I tend to be open about how I am feeling.
33. In discussions I enjoy watching the manoeuvrings of the other participants.
34. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance.
35. I tend to be attracted to techniques such as network analysis, flow charts, branching programmes, contingency planning, etc.
36. It worries me if I have to rush out a piece of work to meet a tight deadline.
37. I tend to judge people's ideas on their practical merits.
38. Quiet, thoughtful people tend to make me feel uneasy.
39. I often get irritated by people who want to rush things.
40. It is more important to enjoy the present moment than to think about the past or future.
41. I think that decisions based on a thorough analysis of all the information are sounder than those based on intuition.
42. I tend to be a perfectionist.
43. In discussions I usually produce lots of spontaneous ideas.
44. In meetings I put forward practical, realistic ideas.
45. More often than not, rules are there to be broken.
46. I prefer to stand back from a situation and consider all the perspectives.
47. I can often see inconsistencies and weaknesses in other people's arguments.

48. On balance I talk more than I listen.
49. I can often see better, more practical ways to get things done.
50. I think written reports should be short and to the point.
51. I believe that rational, logical thinking should win the day.
52. I tend to discuss specific things with people rather than engaging in social discussion.
53. I like people who approach things realistically rather than theoretically.
54. In discussions I get impatient with irrelevancies and digressions.
55. If I have a report to write I tend to produce lots of drafts before settling on the final version.
56. I am keen to try things out to see if they work in practice.
57. I am keen to reach answers via a logical approach.
58. I enjoy being the one that talks a lot.
59. In discussion I often find I am the realist, keeping people to the point and avoiding wild speculations.
60. I like to ponder many alternatives before making up my mind.
61. In discussions with people I often find I am the most dispassionate and objective.
62. In discussions I am more likely to adopt a low profile than to take the lead and do most of the talking.
63. I like to be able to relate current actions to a longer-term, bigger picture.
64. When things go wrong I am happy to shrug it off and 'put it down to experience'.
65. I tend to reject wild, spontaneous ideas as being impractical.
66. It is best to think carefully before taking action.
67. On balance, I do the listening rather than the talking.
68. I tend to be tough on people who find it difficult to adopt a logical approach.
69. Most times I believe the end justifies the means.
70. I don't mind hurting people's feelings so long as the job gets done.
71. I find the formality of having specific objectives and plans stifling.
72. I'm usually one of the people who puts life into a party.
73. I do whatever is expedient to get the job done.
74. I quickly get bored with methodical, detailed work.

75. I am keen on exploring the basic assumptions, principles and theories underpinning things and events.
76. I'm always interested to find out what people think.
77. I like meetings to be run on methodical lines, sticking to laid down agenda, etc.
78. I steer clear of subjective or ambiguous topics.
79. I enjoy the drama and excitement of a crisis situation.
80. People often find me insensitive to their feelings.