A Pedagogical-based Learning Object System to Support Self-regulated Learning

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Abstract: Self-regulated learning has become an important construct in education research in the last few years. Self-regulated learning in its simple form is the learner's ability to monitor and control the learning process. There is increasing research in the literature on how to support students to become more self-regulated learners. However, advancements in information technology have led to paradigm changes in the design and development of educational content. The concept of learning object instructional technology has emerged as a result of this shift in educational technology paradigms. This paper presents the results of a study that investigated the potential educational effectiveness of a pedagogical-based learning object system to assist computer science students. A prototype learning object system was developed based on the contemporary research on self-regulated learning. The system was educationally evaluated in a quasi-experimental study over two semesters in a core course on programming languages concepts. The evaluation revealed that a learning object system that takes into consideration contemporary research on self-regulated learning can be an effective learning environment to support computer science education.

1 INTRODUCTION

The aim of any instructional approach is to provide students with high-quality learning material and educational tools. In the last few years, the concept of self-regulated learning has received increasing attention in educational research, especially higher education research, because of its importance for academic success and lifelong learning (Dettori and Persico, 2008). Self-regulated learning (SRL) focuses on the learner as central in the learning process and on the explicit use of a variety of learning strategies. It is therefore reasonable to gain a greater understanding of the learner, as a precursor to best integrating aspects of self-regulated learning in the teaching and learning process. We argue that the traditional vision of designing and delivering learning material must be altered to place greater emphasis on students' preferences and needs and increase students' control and monitoring of their self-regulated learning.

In accordance with the advancement of educational technology, the current trend in the instructional design of learning material is the use of digital educational resources that have pedagogical objectives as learning objects (Sosteric and Hesemeier, 2002). Learning objects are distributed via online digital libraries known as learning object repositories. There is an increasing effort to develop standards and specifications for these learning objects, but most of this effort focuses on technical development and ignore pedagogy or educational theories, particularly learning styles and self-regulated learning.

Learning objects can improve the teaching and learning of many disciplines. In particular, computer science education has been criticised for a lack of reference to pedagogical theories. The teaching and learning of computer science concepts are challenging tasks for both teachers and students (Ben-Ari, 1998). This has been reflected in the low level of retention and success among computer science students (Biggers et al., 2008). Today, computer science students have diverse backgrounds, experiences and preferences. Computer science involves studying dynamic and abstract concepts that are difficult for students to understand using traditional teaching and learning methods. Computer science is a rapidly changing area that is driven by new technologies rather than pedagogy (Holmboe et al., 2001). Self-regulated learning behaviour is typical of computer science students because they must learn different concepts in a very short time to keep abreast of the dynamic changes in the field (Rodriguez-Cerezo

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et al., 2011).

This paper addresses the challenges associated with the design and use of learning objects to improve the teaching and learning of computer science. A pedagogical framework is proposed to improve the design and use of learning objects based on the concept of self-regulated learning and students' learning styles. The framework is then used to develop and evaluate an online learning object system for a core course on programming languages.

2 SELF-REGULATED LEARNING

Self-regulated learning educational paradigms focus on the role of the learner in the learning process, and view the teacher as facilitative rather than dominant over the learning process. Self-regulated learners are active participants in the learning process who utilise metacognitive, motivational and behavioural strategies (Zimmerman, 1990). Metacognition refers to the awareness and control of the cognition process and includes processes, such as goal setting, planning and self-evaluation to control and monitor the learning process (Pintrich, 2004).

Although various models have been developed to illustrate the process of self-regulated learning, they are all based on Zimmerman's Cyclical Model of Self-Regulated Learning (Zimmerman, 2000). Zimmerman's model views self-regulated learning as an integration process between personal, behavioural and environmental processes. According to this model, self-regulated learning occurs via three cyclical phases: forethought, performance control, and self-reflection (Zimmerman, 2000). These phases are cyclical; feedback from the previous phases is used to adjust the next phase.

The forethought phase involves processes that occur prior to learning, including goal setting and strategic planning. Goal setting is the process of determining the outcomes of the learning task. Strategic planning involves the selection of strategies that are suitable for performing the task. The activation of previous knowledge that is required to accomplish the learning task is essential in this phase.

The performance phase involves processes that occur during learning, such as self-control and self-observation. Self-control involves actual learning strategies that students use to manage the learning material (e.g., reading, note-taking, critical thinking, help-seeking, etc.). Self-observation involves metacognitive monitoring strategies that students may use to track and evaluate their progress, such as self-recording and self-questioning. Students employ the technique of self-recording to record each learning activity and its results. They utilise the strategy of self-questioning or testing to assess their understanding of the learning material by performing a test to evaluate performance against a predefined goal or standard.

Self-reflection involves processes that follow learning, such as self-judgment and self-reaction. These processes are closely associated with self-observation. Self-judgment involves two sub-processes, self-evaluation and causal attributions. Self-evaluation is the comparison of individual performance against predefined goals. It also involves comparisons with the performance of other students in the same class. The result of self-evaluation is linked to the causal attribution to determine the cause of this result. For example, a student's poor performance can be attributed to bad strategy selection, insufficient effort, or limited abilities. Self-judgment is linked to self-reaction. Self-reaction involves two sub-processes, self-satisfaction and adaptive inferences. Self-satisfaction is the learner's perception about his/her performance, i.e., whether the learner is satisfied or disappointed. Based on this perception, the learner employs adaptive inferences to determine how to change the self-regulated learning process to achieve a better result. Adaptive inferences involve changing the goals defined in the forethought phase, or choosing other strategies to perform the task.

3 LEARNING STYLES

Learning is the process whereby individuals acquire new knowledge. Research indicates that students tend to gather and process information in different ways. These differences are known as learning styles. Many definitions of the term 'learning style' can be found in the literature. Keefe (Keefe, 1988) defines learning style as the characteristic cognitive, affective and psychological behaviors that serve as relativity stable indicators of how learners perceive, interact with and respond to the learning environment. This is one of the most comprehensive definitions of the learning style, and is adopted by the National Association of Secondary School Principals.

3.1 Summary of Research on Learning Styles

Education researchers agree there are different learning styles that must be accommodated to improve the teaching and learning process. In addition, empirical studies on the implications of different learning styles for students' performance have found significant differences in the levels of academic achievement of students with different learning style (Akdemir and Koszalka, 2008). One explanation for this result is that the learning materials favour specific learning styles and ignore other styles.

There is current debate on how to integrate learning styles into curriculum design and teaching and learning activities. Lack of empirical studies that evaluate the effectiveness of learning styles-based interventions has made it difficult to generate recommendations for teachers and curriculum designers. The research on learning styles focuses primarily on identification of students' learning styles, and how this might affect their academic achievements. In addition, research on learning styles follows a track that differs from that of other educational theories. The role of learning styles in self-regulated learning has not been investigated and appears to offer a potential direction for future research.

The main hypothesis that dominates research on learning styles is called the matching hypothesis (Coffield et al., 2004). This hypothesis argues that if a learner is presented with learning material that is compatible with his/her own learning style, his/her learning process improves. Further, teaching methods that are mismatched with the learner's style might lead to difficulties in learning. However, research on how this hypothesis could be applied in context to improve the teaching and learning process in many disciplines, including computer science, is scarce. Learning style awareness was proposed in response to critical reviews of learning style theories as an alternative and promising hypothesis for future research on learning styles (Coffield, 2004). This hypothesis claims that knowledge of learning styles should be used to increase self-awareness, which leads to improvements in the learning and teaching process. Learners who become aware of their learning styles are more likely to be aware of their strengths and weaknesses and, therefore, have greater control of their learning processes. In addition, teachers who are aware of the diversity of learning styles amongst their students are most likely to adopt teaching approaches that appeal to different types of students. In this case, knowledge about learning styles is used to enhance metacognition, which is an important component in any self-regulated learning model.

3.2 Felder-Silverman Learning Style Model

Learning styles can be identified using different learning style models. There are many learning style models proposed in the literature. The FelderSilverman Learning Style Model (Felder and Silverman, 1988) is a well-known learning style model that is heavily used to identify students' learning styles in many disciplines, especially in science and engineering education. The Felder Silverman Learning Style Model has been adopted in this study as the basis for identifying students' learning styles due to many reasons, some of them are the following:

- It covers more than one level of learning style, thus provides categorisation of students' learning styles based on multiple dimensions.
- It has been used to investigate the learning styles of engineering students, groups of learners similar to the target population of this study (e.g., (Felder and Brent, 2005)) .
- The instrument used by this model is reported to have satisfactory level of reliability (Felder and Spurlin, 2005).

The Index of Learning Styles (ILS) is the instrument that is used to identify learning styles based on this model. This model consists of four dimensions (Felder and Silverman, 1988):

Perception (Sensing/Intuitive): this dimension describes the type of information an individual preferentially perceives. Sensing learners prefer concrete contents and facts, and are detail-oriented, whereas intuitive learners prefer abstract concepts, theories, and mathematical formulas, and dislike details. Sensing learners tend to solve problems using well-established methods, and dislike complications. Intuitive learners like innovations, new ideas of solving problems, and dislike repetition.

Input (Visual/Verbal): this dimension describes the type of presentation an individual prefers. Visual learners prefer learning through visual media, such as pictures, charts, and diagrams, whereas verbal learners prefer spoken or written materials and explanations. Both types of learners learn better when the material is delivered using visual, verbal, and written forms.

Processing (Active/Reflective): this dimension describes how the learner processes information. Active learners prefer learning in groups, and they tend to try things out, whereas reflective learners prefer working alone, and tend to think about how things work before attempting them.

Understanding (Sequential/Global): this dimension describes how the learner progresses towards understanding information. Sequential learners prefer following a logical, step by step linear approach, whereas global learners prefer absorbing the learning materials randomly, in large jumps, without following a step by step approach, until they grasp the full picture. Global learners need to grasp the full picture before going into the details. Courses are normally taught according to a sequential presentation format. Sequential learners can learn effectively under this method of instruction.

4 LEARNING OBJECT SYSTEMS

Advances in information technology have led to a paradigm shift in the way that people communicate and learn. Consequently, the development and delivery of learning materials are changing. To reflect this paradigm shift, a new instructional technology called learning objects emerged as a next generation technique for instructional design, due to its capacity for reusability, adaptability and scalability (Hodgins, 2002).

Increased interest in the concept of learning objects has led to a number of definitions and terms to describe the idea behind learning objects. Sosteric and Hesemeier(Sosteric and Hesemeier, 2002) synthesised several definitions and defined a learning object as ”a digital file (image, movie, etc.) intended to be used for pedagogical purposes”. A learning object can be published through a variety of methods. The most formal method of publishing learning objects is through learning object systems. A learning object system is any online platform or environment that is used to facilitate authoring, indexing, distributing, and delivering of learning objects (Ritzhaupt, 2010). A learning object system uses a database in which learning objects are stored along with their metadata to be shared. These databases are usually knows as learning object repositories.

Learning objects can support students in their self-regulated learning of, for example, computer science if pedagogical foundations are considered during the design and delivery of these learning objects. There is a paucity of underlying theory that guides the design and use of learning objects (Wiley, 2000). Moreover, the delivery of learning objects in online learning object systems does not follow a predefined pedagogical model based on the latest research in self-regulated learning (Alharbi et al., 2011a).

5 PEDAGOGICAL-BASED LEARNING OBJECT SYSTEM

Education research on learning styles, and that on self-regulated learning, appears to be isolated from one another. Self-regulated learning models that consider the diversity of students' learning styles have the potential to provide a comprehensive understanding of the learning process (Cassidy, 2011). This leads us to return to the metacognitive component of self-regulated learning, which concerns the importance of the learner's awareness and ability to control his/her cognition process. According to this component, learning styles can be used to improve the metacognitive process, which in turn enhances students' motivation and learning. In this way, the future research on self-regulated learning and learning styles can interact to provide a basis for empirical studies that can produce pedagogical recommendations for teachers and instructional designers.

This study presented in this paper synthesises contemporary educational research to provide a greater understanding of the theory of learning styles by placing it in the context of self-regulated learning models. The result of this synthesis is a pedagogical self-regulated learning framework with learning style as one of its main components (Alharbi et al., 2011b). This framework can be used as the basis for improving learning and teaching in many disciplines. However, in the current research, the framework is applied to improve the design of learning object instructional technology in computer science education.

5.1 System Components

Based on the proposed pedagogical framework, the current study develops and evaluates a learning object system with self-regulated learning support. Figure 1 shows the main components of the proposed learning object system.

5.1.1 Learning Object Repository

The learning object repository is responsible for storing different learning objects that are designed to support students in learning about programming languages concepts. This repository stores all learning objects along with their optional XML files that describe the structure of learning objects, and define the animation inside the learning object. All the learning objects are stored in the repository and tagged with relevant metadata to make it easy for students to find them.

5.1.2 Learning Style Awareness Module

The objective of this module is to increase students' awareness of their learning styles and their use of self-regulated learning strategies. This module consists of an initial assessment of students' use of self-

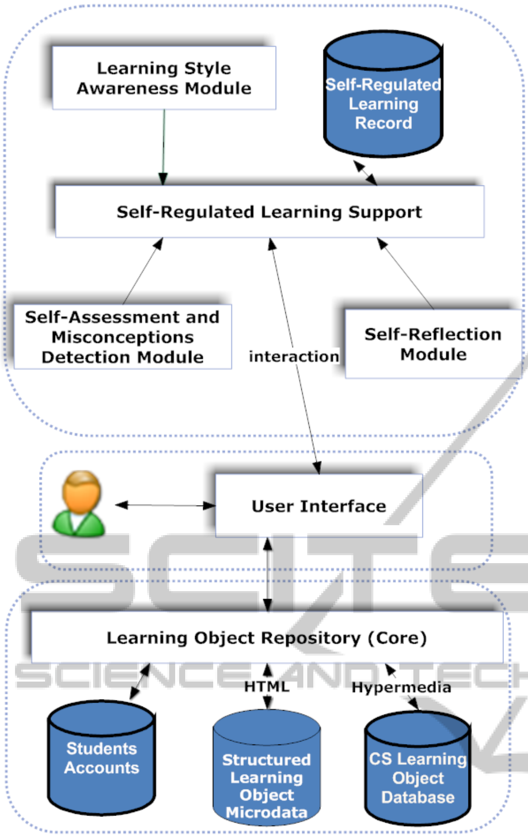

Figure 1: Learning Object System Components

regulated learning strategies and the identification of students' learning styles. A research instrument is used to measure students' self-regulated learning strategies. The learning strategies are categorised based on the research on self-regulated learning. The Index of Learning Styles (ILS) is used in this module to identify students' preferred learning styles based on Felder-Silverman learning style model (Section 3.2) This model describes the learner's preferences based on four dimensions, Sensing-Intuitive, Visual-Verbal, Active-Reflective and Sequential-Global. Upon first login to the system, the student is redirected to complete the learning style assessment. After completing the assessment, the module evaluates the responses and determines the student's preferred learning style. The module increases students' awareness by providing the result, together with a description and recommended learning strategies. Although students are permitted to access all learning objects in the system, the recommended learning strategies consider the strengths and weaknesses of students' preferred learning styles.

5.1.3 Self-assessment and Misconceptions Detection Module

This module is responsible for generating self-assessment questions that help students detect their misconceptions related to the programming languages concepts. These self-assessments are associated with the learning objects that are designed to help students overcome these misconceptions. This module is also responsible for recording each student's self-assessment results in the self-regulated learning record. Each assessment exercise is linked to a specific misconception about programming languages concepts. Learners are given instant feedback after completing each assessment.

5.1.4 Self-reflection Module

Meta-cognition is the most important self-regulated learning process that requires greater attention in online educational environments. This module extracts information from the analysis of students' behaviours, which is stored in the self-regulated learning record, and uses this information to help students develop self-reflection skills. To detect a specific misconception, a number of questions are developed and integrated into the self-assessment. The self-reflection support module extracts information from the results of self-assessments that are stored in the self-regulated learning record, and uses them to calculate the degree of misconception related to a specific concept. In addition, when a misconception is listed in the student's self-regulated learning record interface, the module shows information on the proportion of students with this misconception. This information is shown to the leaner to encourage him/her to overcome these misconceptions. The learner can view additional information on the possible reasons behind these misconceptions, and how to overcome them by considering his/her learning styles. The module also allows a student to view detailed information on his/her behaviour inside the system, including the time spent on each learning object compared to the time spent by other students, and the results of the self-assessment exercises.

5.1.5 Self-regulated Learning Record

The Self-Regulated Learning Record (SRLR) is a proposed component that records the user's interactions with learning objects and other educational tools. The self-regulated learning record provides an alternative approach for the communication between LMS and different types of learning objects. The content of the self-regulated learning record can be accessed by any

LMS or educational tool, which in turn supports self-regulated learning. In the proposed online learning object system, the SRLR stores information related to the learner and his/her use of learning objects. This information includes the following:

- Time student spent on each learning object per session..
- The results of students' learning styles and learning strategies assessments.
- The results of students' self-assessments.
- Students' navigation behaviour in each session.

6 EVALUATION METHODOLOGY

This section presents details of the research methodology that was adopted to evaluate the educational effectiveness of the proposed learning object system. These details include a description of the research participants, design, and procedure. In addition, the instruments that were used to collect the data are described. This section concludes by describing the data analysis techniques used to analyse the data and how the results were interpreted to test the hypotheses and answer the research questions.

6.1 Research Design: Quasi-experimental Study

The qualitative portion of the study follows a quasi-experimental control group design with pre-tests and post-tests (Creswell, 2012). Quasi-experimental design is the same as the control experimental design except that the participants are not randomly assigned to the experimental conditions. Rather, intact convenience groups are used. This design is commonly used in educational research due to difficulties associated with randomly dividing participants into groups. The purpose of the experiment is to determine the effect of the proposed educational intervention on students' academic achievement in a core computer science course.

6.2 Description of the Course and Participants

The participants in this study are students enrolled in the programming languages and paradigms course at the University of Newcastle, Australia, in the first semesters of 2011 and 2012 respectively. The overall sample size was 62 students: 34 in 2011 (control group) and 28 in 2012 (experimental group).

The online learning object system is used and evaluated in the course Programming Languages and Paradigms. A course that covers programming language concepts is important for computer science and software engineering students and such a course is an integral part of any computer science and software engineering program (IEEE/ACM, 2005). Programming language concepts are presented by comparing the features of programming languages, such as Java and C++. In addition, several programming paradigms are discussed and compared. The Programming Languages and Paradigms course at the University of Newcastle is a compulsory second year course for undergraduate students enrolled in the computer science and software engineering programs. The course follows a traditional teaching method that consists of weekly lectures and workshops.

6.3 Data Collection Instruments

A number of data collection instruments were utilised to address the research the following research questions:

- What is the effect of the proposed learning object system on students' academic achievement?
- To what extent are students satisfied with the educational effectiveness of the system?

The following instruments were used to collect both quantitative and qualitative data.

6.3.1 Students' pre- and post-tests

Students tool the pre-test in both the experimental and control groups at the beginning of the semester, and before the experimental group was introduced to the online learning object system. The pre-test consists of questions to help students refresh their knowledge about several object-oriented and data structures concepts, and how to apply them to solve a real-world problem.

6.3.2 Students' Satisfaction Questionnaire

This instrument is an online questionnaire completed by students to evaluate the educational effectiveness of the entire learning object system at the end of the semester. This instrument includes questions about students' perceptions of the educational effectiveness of the online learning object system. The questionnaire utilises a 7-point Likert scale, with 1 representing strongly disagree and 7 representing strongly agree. The questionnaire consists of dimensions that are related to a specific feature of the online learning object system. Each dimension has a number of questions.

6.3.3 Self-regulated Learning Record

Self-Regulated Learning Record (SRLR) is a component of the online learning object system that automatically logs all activities performed by students in each session. This includes the frequency and time spent on learning objects and the results of students' self-assessments. Also, the students' navigation behaviour in each session can be discovered by extracting the information stored in the SRLR. The data collected using the SRLR was used to study students' behaviour inside the system.

6.4 Method and Procedure

The study was conducted in two consecutive phases. In the first phase (first semester 2011), the control group did not receive intervention and were taught using the traditional instructional approach. In the first week, students were given an information statement that described the research objectives and invited them to participate. Those who agreed to participate signed a consent form that indicated that they were willing to participate in the research study as described in the information statement. Then, the Index of Learning Style (ILS) was administered to students who signed the consent form to identify their preferred learning styles. In addition, the Self-Regulated Learning Strategies Questionnaire was administered to students to measure the level of use of different self-regulated learning strategies. In the second phase (first semester 2012), the experimental group received the online learning object system as an educational intervention to aid in developing self-regulated learning strategies while studying the course material. The Index of Learning Style (ILS) was given to the students at the beginning of this phase using the same questionnaires that were used in first phase. However, in the second phase, additional research instruments were used to measure the educational effectiveness of different aspects of the research intervention. These include the students' satisfaction questionnaire and the self-regulated learning record.

7 RESULTS AND DISCUSSIONS

7.1 The Result of the Quasi-experimental Study

The first step to evaluate the educational effectiveness of the intervention is to report descriptive statistics that describe the academic performance of the students in the control and the experimental groups. The second step is to perform hypothesis testing. This is the formal procedure used by statisticians to accept or reject hypotheses. The statistical level of significance (α) is set to 0.05 for hypothesis testing. The analysis also evaluates the influence of students' learning styles and level of self-regulated learning on their academic performance in both groups. An analysis of students' behaviour in the online learning object system was also conducted. An analysis of covariance (ANCOVA) was used to measure the difference between the control and the experimental groups while taking into consideration the possibility of pre-existing differences between the two groups.

In the control group, the mean final exam score was 55.2, while it was 65.3 in the experimental group. To test whether this difference is statistically significant, a one-way analysis of variance (ANCOVA) was used. The following hypotheses were formulated:

H0: *there is no significant difference in the final exam scores between the control and the experimental group.*

HA: *there is a significant difference in the final exam scores between the control and the experimental group.*

The independent variable is the medium of instruction, which consists of two levels, traditional or intervention. The dependent variable is students' achievement scores on the final exam. Students' scores on the pre-test were considered as the covariate in the ANCOVA to control for the pre-existing differences between the control and the experimental groups (Table 1).

Table 1: The result of the statistical test for the final exam scores comparison.

Group	N	M	SD	F	P
Control	34	55.2	15.9	9.83	0.003*
Experimental	28	65.3	19.5		

The result of the ANCOVA was significant ($F = 9.83$, $p = 0.003 < 0.05$). Based on this result, the null hypothesis (*H0*) was rejected and we accepted the alternative hypothesis (*HA*) that the difference in the mean final exam scores between the experimental and control groups is statistically significant. Students in the experimental group (M=65.3, SD=19.5) significantly outperformed those in the control group (M=55.2, SD=15.9) on the final exam after considering the pre-test scores as a baseline for both groups. Thus, regardless of the pre-existing difference in students' achievement on the pre-test between the study groups, the online learning object system had a statistically significant positive effect on the final exam scores of the experimental group.

7.2 Students' Satisfaction

At the end of the semester, the final feedback questionnaire was made available online inside the learning object system. This questionnaire measured students' degree of satisfaction with the learning object system. The satisfaction questionnaire consists of a number of dimensions; each measures students' satisfaction in terms of their perceptions about a specific feature of the online learning object system Nineteen (experimental group) students completed the questionnaire at the end of the course. This section summarises the analysis of students' responses to the questions related to each dimension in the questionnaire. Each dimension consists of a number of questions. Students responded using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The average percentage of students who responded to each level of the Likert scale was calculated for each dimension.

The first dimension of the questionnaire measured students' satisfaction with the online learning object system in terms of their perceptions about the ability of the system to correctly identify their preferred learning style, and the system's recommendations and guidelines. The result is presented in Figure 2. The majority of students (93%) had a positive perception of the learning style identification and awareness module. They considered it to be useful in providing recommendations and guidelines that reflected their preferred learning styles. The majority of students agreed that the system helped them to identify their preferred learning styles and that the learning strategies were easy to follow and useful. The result indicates that the system helped students gain awareness of their learning styles. Thus, many of them will be aware of their learning styles in their future studies, and should be able to use this knowledge to aid their self-regulated learning, utilising the strengths of their learning styles and overcoming their weaknesses.

The second dimension of the questionnaire measured students' satisfaction in terms of perceptions about the self-reflection support module which was used in the system to help students monitor and control the self-regulated learning process. Figure 3 shows that 72% of students agreed that the self-reflection support module, which was used to record students' interactions with learning objects, information related to their misconceptions, and indicators of their progress, was educationally effective. Of the students, 16% had a neutral opinion and 12% disagreed with the educational benefit of the self-reflection support module.

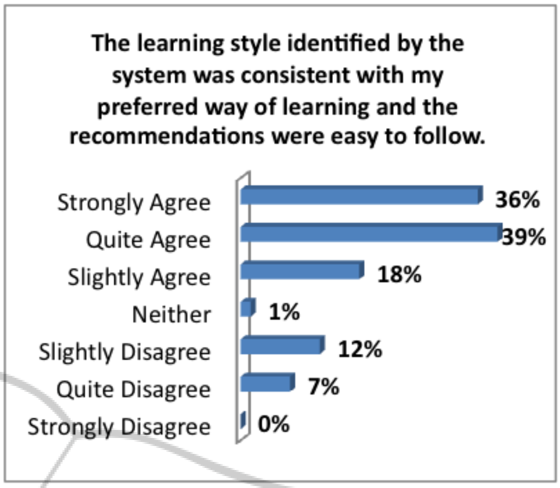

Figure 2: Students' satisfaction with the learning style awareness module.

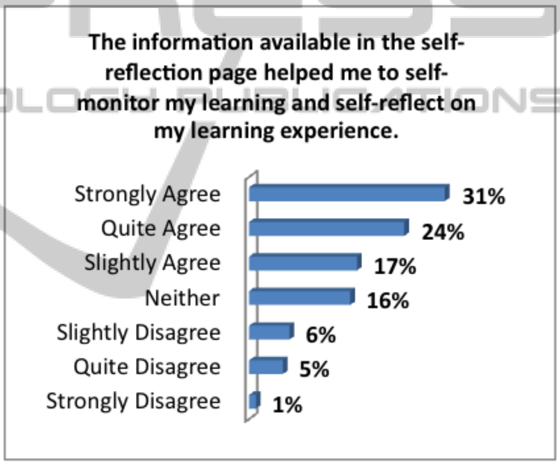

Figure 3: Students' satisfaction with the self-reflection module.

The last dimension measures students' overall perceptions of the idea of using online learning object systems to support self-regulated learning. The result is presented in Figure 4. The final result of the questionnaire indicates that 94% of the students agreed with the statements comprising this dimension. Nearly all students strongly supported the idea of applying online learning object systems to other computer science courses.

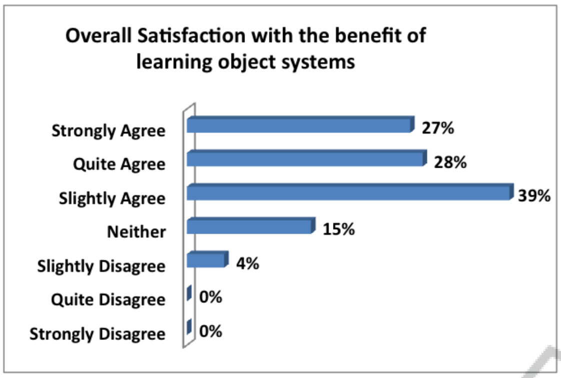

Figure 4: Students' satisfaction with the idea of learning object systems.

7.3 Analysis of Navigation Behaviour

Trace analysis of students' navigation behaviour was conducted to study students' behaviour inside the system, using the information recorded in the self-regulated learning record. Based on the self-regulated learning model used in this study, we proposed a navigation behaviour analysis method to classify learners' self-regulated learning behaviour. A number of navigation behaviour patterns were observed. We conducted further analysis only on the patterns that were followed frequently. These patterns were categorised as follows:

Browsing: this behaviour implies that students jump between different pages inside the system in the same session without spending more time on the learning objects or their self-regulated learning record.

Unplanned View of Learning Objects: this behaviour implies that students view learning objects that are most likely not related in the same session. Students who adopted this behaviour typically did not complete a self-assessment after viewing the learning object.

Inefficient Use of Self-assessments: this behaviour implies that the student tends to take self-assessments for different topics in the same session without or with a limited view of learning objects and their self-regulated learning record inside the system.

High Level of Meta-cognition: this behaviour implies that students tend to follow a navigation path that is consistent with the self-regulated learning model. They tend to view their self-regulated learning record at the beginning of each session, then view learning objects related to one topic only, complete self-assessments and spend time reading the feedback after submitting the self-assessment. They also tend to make decisions based on their results in the self-assessments, such as viewing learning objects again and then completing the self-assessment again.

Table 2: Navigation behavior patterns.

Navigation pattern	Proportion of students
Browsing	14%
Unplanned view of learning objects	14%
Inefficient use of self-assessments	18%
High level of meta-cognition	54%

The proportion of students who frequently adopted each navigation pattern is presented in Table 2. More than half of the students (54%) adopted a behaviour pattern that reflects a high level of meta-cognition inside the online learning object system. Of the students, 18% showed a tendency to adopt navigation behaviour that reflected inefficient use of the self-assessment exercises and 14% frequently adopted a behaviour that reflected browsing behaviour or unplanned view of learning objects.

Further analysis of the data was conducted to investigate the influence of the most frequently adopted navigation behaviour pattern on students' academic achievement as measured by the post-test. To facilitate the analysis, the three groups who did not adopt the meta-cognition pattern frequently were combined together to form one single group (non meta-cognition). After that, an ANCOVA test was conducted to test if there is any significant difference in the post-test scores between students in the meta-cognition pattern and the non-meta cognition pattern groups, after controlling for their pre-test scores. Table 3 presents the result of the ANCOVA statistical test.

Table 3: Navigation patterns.

Navigation pattern	Mean	SD	F	P
Meta-cognition	74.9	12.2	7.68	0.010*
Non meta-cognition	54.3	20.9		

Table 3 shows that the meta-cognition behaviour pattern group had higher post-test scores (M=74.9, SD=12.2) than the non meta-cognition group (M=54.3, SD=20.9). The result of the ANCOVA test confirms that this difference is statistically significant after adjusting for the pre-test scores, ($F=7.68$, $p=0.010<0.05$). To sum up, students who adopted the meta-cognition behaviour pattern more frequently had higher academic achievements as measured by the post-test.

8 CONCLUSIONS

This paper presented the result of an empirical study that evaluated the educational effectiveness of an online learning object system to support self-regulated learning of programming languages concepts. The system design was based on a pedagogical framework that was adopted to improve the role and impact of learning object repositories. The result of the study revealed that the learning object system is an effective intervention in supporting students as self-regulated learners. This was also reflected in the results of the students' satisfaction questionnaire, which showed that the students had positive perceptions of the features of the system.

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