Enhancing Logical Thinking among Computer Science Students through Cooperative Learning

Mahfudzah Othman
Faculty of Computer & Mathematical Sciences
Universiti Teknologi MARA Perlis
fudzah@perlis.uitm.edu.my

Fazlin Marini Hussain
Faculty of Computer & Mathematical Sciences
Universiti Teknologi MARA Pahang
fazlinmarini@pahang.uitm.edu.my

Khairunisa Nikman
Academy of Language Studies
Universiti Teknologi MARA Pahang
yune@pahang.uitm.edu.my

ABSTRACT

This study is aimed to investigate the logical thinking levels among first semester students who enrolled in the introductory programming course in Computer Science studies. A selected group of ninety-seven students were asked to take the Group Assessment Logical Thinking (GALT) tests in the beginning and at the end of the semester. The results derived from the GALT pre-tests will be used to divide the students into learning groups, where each group consists of two High Logical thinkers (HLT) and two Low Logical thinkers (LLT). Afterwards, the Cooperative Learning (CL) method which is named Numbered Heads Together is then introduced in the programming classes. Later, at the end of the semester, the GALT post-test results are then being compared with the pre-test results to see the changes of logical thinking levels among the students. The results have shown an increasing number of students with HLT levels. Due to the effectiveness of practicing CL method in classes, a proposed framework for an online collaborative learning system is also being discussed in this paper. Another technique called Think-Pair-Share is being selected to suit the virtual environment. It is hoped that the cooperative learning methods whether the in-class practice or online collaboration will be seen as an innovative way to enhance the students' logical thinking levels thus improving their performances in programming courses.

Keywords: *cooperative learning, logical thinking, online collaborative learning system*

Introduction

Learning to program is generally considered hard, and programming courses often have high dropout rates as claimed by Lahtinen et.al (2005). It is also had been said that it takes about ten years for a novice to become an expert programmer (Soloway & Spohrer, as cited in Ala-Mutka, n.d., p.2). Most of the skillful programmers agreed that the art of programming includes knowledge of programming tools and languages, problem-solving skills, and effective strategies for program design and implementation. In today's education system, a common approach in programming education is to first teach the basics of a programming language and then guide students towards effective strategies for the whole programming process (Ala-Mutka, n.d., p.1).

However, most of us fail to realize that one of the crucial factors that determine the capability of the students in learning programming is their logical thinking. Regarded as a universal human trait, the ability to think logically, following the rules of logical inference, has traditionally been defined as a higher cognitive skill (Zoran, 2008). According to Piaget, there are four stages of cognitive development (as cited in Atherton, 2005), as shown in Table 1.

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Table 1: Stages of Cognitive Development

Stage	Characterised by
Sensori-motor (Birth-2 yrs)	Differentiates self from objects. Recognizes self as agent of action and begins to act intentionally: for instance, pulls a string to set mobile in motion or shakes a rattle to make a noise. Achieves object permanence where a child realizes that things continue to exist even when no longer present to the sense.
Pre-operational (2-7 years)	Learns to use language and to represent objects by images and words. Thinking is still egocentric meaning the child has difficulty taking the viewpoint of others. Classifies objects by a single feature: for instance, groups together all the red blocks regardless of shape or all the square blocks regardless of color.
Concrete operational (7-11 years)	Can think logically about objects and events. Achieves conservation of number (age 6), mass (age 7), and weight (age 9). Classifies objects according to several features and can order them in series along a single dimension such as size.
Formal operational (11 years and up)	Can think logically about abstract propositions and test hypotheses systematically. Becomes concerned with the hypothetical, the future, and ideological problems.

Logical thinking can be described as a skill which is determined in the period of abstract process in the Piaget's cognitive development phase. With logical thinking skills, learners solves the problem by doing various mental practices or reaches principals or rules by doing some abstraction and generalization (Yaman, 2005).

Albrecht (1984) added that logical thinking is not a magical process or a matter of genetic endowment, but a learned mental process. It is referred to as the process in which one uses reasoning consistently to come to a conclusion. Problems or situations that involve logical thinking call for structure, for relationships between facts, and for chains of reasoning that is logic or in other word, solution that makes sense. Albrecht (1984) also claimed that the basis of all logical thinking is the sequential thought. This process involves taking the important ideas, facts, and conclusions involved in a problem and arranging them in a chain-like progression that takes on a meaning in and of it. Meaning that; to think logically is to think in steps.

Logical thinking is also claimed as an important foundational skill of mathematics and computer programming. This is because, in both fields, mathematics and computer science require highly sequential processes. For example, in Mathematics, to understand fractions you must first understand division. Whereas, in developing a computer program, one has to be able to produce an algorithm that shows the sequence of steps to produce the right solution to the problem (Malik, 2004). This process is often referred to as a problem-solving process.

Problem Statement

However, we have to realize that students have different logical thinking levels where they have different abilities to use several thinking patterns to understand computer programming problem, analysis and specification. Some studies have claimed that students need to acquire logical and reasoning as well as analytical thinking in developing the solution of the problem (Mohd Nasir, et.al, 2006). These differences of cognitive characteristics among

students explained why some of the students succeeded in computer programming courses and some of them failed to complete the course with flying colors (White, et.al, 2002).

Therefore, the main objective of this study is first to investigate the logical thinking levels among Computer Science students. The aim is to measure how many of them have already had higher logical thinking levels and how many of the students who are low logical thinkers. Later, the cooperative learning technique will be introduced in the computer programming classes. The objective is to see whether the students' logical thinking levels will change after the cooperative learning technique is implemented in the classes.

Furthermore, due to the rapid change of information technologies nowadays, another method will be proposed in this study which is the online collaborative learning system. This online system is inspired by the effectiveness of in-class cooperative learning method. However, although there are lots of e-learning portals and websites available on the Internet nowadays, there are still lack of studies have been made about using the online system to support learning in programming courses especially systems that support asynchronous learning. Therefore, the proposed online system framework is aimed to become one of innovative ways to integrate the cooperative learning technique in a virtual environment thus improving the logical thinking levels among students in Computer Science studies.

What is cooperative learning?

Cooperative learning can be described as a structured, systematic instructional strategy in which small groups work together toward a common goal (Cooper & Mueck, 1990). With cooperative learning, it will focus on helping students to plan and design their problem solving strategy and also guide them to plan, understand, monitor, and evaluate as well as reason their learning.

In practical term, Slavin (1983 and 1995) and Sharan et al. (1984) define cooperative learning as students working together to achieve common learning goals (as cited in Nunan, 1992, p. 3). O'Malley and Chamot (1990) also share the same view as they state that this learning style involves social strategies in which students work together in heterogeneous small groups toward a common goal (p.169). In other words, cooperative learning can also be depicted as concepts and techniques for enhancing student-student interaction. The social interactions involved could be as simple as having the students in pairs to discuss a reading text or assigning them in groups to complete a project paper. Each team member is responsible not only for his or her own learning of what is taught but also in helping other teammates to learn, thus creating a better learning environment. All members of the team work together on the assigned task until everybody successfully understands and completes it.

There are several developers of cooperative learning theory, yet the most well-known ones would include Robert Slavin, Roger and David Johnson and Spencer Kagan. They have also introduced several structures or approaches to cooperative learning, for example, Slavin is associated with Student Team Achievement Division (STAD) while Kagan develops a Structural Approach (Olsen & Kagan, 1992, in Kessler, 1992). Based on these structures, numerous cooperative learning activities have been developed to assist teachers and educators to practise cooperative learning in classrooms, such as 'Think-Pair-Share', 'Jigsaw', 'RoundRobin', and 'Numbered Heads Together'.

Online Collaborative Learning System

In order to teach and learn collaboratively, online collaborative learning system should be supported by a specific tool. Therefore, it is can be closely related to Computer-Supported Collaborative Learning (CSCL). CSCL is considered as one of the most promising innovations to improve teaching and learning with the help of modern information and communication technology (Nik Azlina, 2008).

Nik Azlina (2008) added that the models of collaboration for computer-supported learning are focusing on one dimension of potential collaborations, such as: peer-peer; child groups; adult-child; or computer-child interactions. Furthermore, Mahdizadeh (2007) also claimed that CSCL can be used to enhance peer interaction and group work where the online collaboration and technology used will facilitate the sharing and distribution of knowledge and expertise among community members.

In addition, Gros et al. (2005) mentioned that computer-supported collaborative learning expresses two important ideas which are the idea of learning collaboratively online with others and also in a group. It can be described that the learner is not seen as an isolated person but rather in interaction with others via the networked

computers. It is based on the idea that sharing goals and distributing responsibilities are desirable forms of learning. It is therefore a process where the individual learns to collaborate and collaborates in order to learn (Mahdizadeh, 2007). Furthermore as added by Nik Azlina (2008), computer-supported collaborative learning (CSCL) applications are powerful e-learning environments that facilitate interaction, negotiation, and collaboration amongst and between students and their teachers and external information sources in order to construct new knowledge.

Therefore, it can be concluded that CSCL is a method for bringing the benefits of collaborative learning to users via Internet and the Web. Among the benefits are, CSCL can support the communication of ideas and information among learners, collaborative accessing of information and documents, and instructor and peer feedback on learning activities (Nik Azlina, 2008).

Materials & Methods

The research method of this study will be divided into four phases as explained below:

Phase 1: The selection of the sample of respondents

The population of this study was the computer science students enrolled for a Diploma in Computer Science at Universiti Teknologi MARA Pahang. The sample consisted of ninety-seven male and female students enrolled in the first semester computer programming course from two selected semesters; which are July 2007 intake and July 2008 intake. The age of the sample group ranged between 18-19 years and their Mathematical results from Sijil-Pelajaran Malaysia (SPM) ranged between A1 and A2. Before the research is conducted, the programming classes are taught to heterogeneous classrooms with no grouping or ability tracking.

Phase 2: The Group Assessment Logical Thinking (GALT) Test

At the beginning of the semester, students were asked to complete a Group Assessment Logical Thinking (GALT) test which in this case we labeled it as pre-test. The GALT test consisted of twelve items measuring conservation of weight and volume displacement, proportional thinking, identification and control of variables, probalistic thinking, correlational thinking, and combinatorial thinking posed in a pencil-and-paper format (Roadrangka, Yeany, & Padila, 1983). The instrument used double answers for each question; multiple choice formats for presenting options for answers, and a justification or reason for each answer. The justification for answers provided more insight into student's logical thinking ability as well as greatly reducing the guess factor. The students would be given one point for each item for which a correct response is given for both answer and justification.

In completing the test, the students were given one hour of class period. The test items in GALT instrument used pictorial representations of objects and the reading level are suitable for university students. Students with a score of 0 to 6 will be considered to be low logical thinking (LLT) students whereas students who accumulated score from 7 to 12 points will be classified as high logical thinking (HLT) students.

Phase 3: Cooperative Learning (CL) Method and GALT post-tests

In this phase, the students were divided into learning groups based on their GALT pre-test results. Each group consists of two HLT and one or two LLT students. At this stage, the cooperative learning method will be incorporated to complete a computer programming tasks. In this study, the method of cooperative learning used is based on the Structural Approach (Kagan, 1989 & 1994). This structure is relatively easy to implement and can be categorized into team and class building, communication, mastery, and critical thinking structures. The structure to be used is known as Numbered Heads Together. The procedures of Numbered Heads Together, as described by Kagan (1989), are as follows: First, the students will be numbered off within teams. Secondly, the lecturer will ask a question. Thirdly, students will discuss to ensure everyone in the team knows the answer. Lastly, the teacher will call a number at random, and students with that number raise their hands to be called upon to answer the question and earn points for their teams.

Throughout the semester, there were four group assignments that had to be completed by each group. The group assignments were based on the chapters in the Fundamental of Computer Problem Solving (formerly known as CSC125) course syllabus constructed by Faculty of Information Technology and Quantitative Sciences, UiTM

Malaysia. Each group assignments were being marked and the average mark for each assignment was recorded. Finally, at the end of the semester, the students were required to take the GALT test again which is called the post-tests. This was carried out to see whether there were any changes or improvement in the students' logical thinking level or not.

Phase 4: Conceptual framework of Online Collaborative Learning System

In this phase**,** a conceptual framework of online collaborative learning system is being constructed. This framework is being developed due to the fact that the in-class practice of cooperative learning method has shown positive effects to the students' abilities to think logically. However, due to the complexity of Numbered Heads Together technique used in the second phase, another technique known as Think-Pair-Share has been chosen to suit the virtual environment.

In traditional Think-Pair-Share technique, there are three stages that students have to undergo as described by Nsw (2006). The first stage is the Think stage where each student thinks about the task or topic, taking notes or jotting down ideas. This stage gives students a chance to write down their answer before discussing it with their pair. The teacher may collect written responses from each student before allowing them to continue to the Pair stage. In the second stage, which is the Pair stage, the pairs of students then discuss their thoughts and ideas about the task or the notes taken, before come out with a conclusion from the pair discussion. The pair will then create a new answer that incorporates the best of the ideas. Lastly, at the Share stage, pairs will be asked to share their thoughts with the rest of the class. The pairs then discuss their group thoughts and ideas about the task or discussion point.

Think-Pair-Share is a relatively low-risk and short collaborative learning technique, and therefore, it is ideally suited to implement the technique in the virtual environment. The online collaborative learning system is developed using the web-based applications where it can support multi-users simultaneously from dispersed locations thus supporting online discussions, instant messaging services and emails between the users.

Results & discussion

As mentioned before in the first phase, the selected groups were chosen from the first semester students from two batch semesters. In the second phase, at the beginning of each semester, the students were asked to take the GALT pre-test to determine their logical thinking levels. Table 2 below shows the differences of logical thinking levels among students in introductory programming course at the beginning of the semester.

Table 2: Frequency of logical thinking levels among first semester students based from GALT pre-test results

Logical	JUL-NOV	%	JUL-NOV	%
HLT	26	56.5%	32	62.7%
LLT	20	43.5%	19	37.3%
TOTAL	46	100.0%	51	100.0%

From the Table 2 above, we can see that the percentages of students who are high logical thinkers (HLT) are higher in both semesters. There are more than 50% of them who were HLT students and approximately 40% were LLT students.

Based on the results of the GALT pre-test, the students were then divided into learning groups which is done in the third phase of this study. There were about twenty-nine learning groups altogether from every batch semesters. These groups were asked to complete four group assignments that were based on the chapters in CSC125 course syllabus. The descriptions and total marks for each assignment are described in *Table 3* below.

Table 3: Descriptions and total marks for group assignments

Assignment	Description	Total Marks
1	Sequential structure: Write the algorithm to solve the problems	18
2	Selection structure: Write the algorithm and complete program to solve the problems	30
3	Repetition structure: Write a complete program using looping, selection structure and functions	13
4	Functions: Write a complete program using functions	17.5

Each one of the learning group was asked to complete each question within an hour. The cooperative learning method, which is Numbered Heads Together, was used in this study where each one of the team members holds a number within their teams. They were then asked to discuss and thoroughly understand the problem domain and then came out with the right solution. Each one of the team members must understand and successfully solve the problem and the lecturer will call any number within the team randomly for them to present the solutions of the problem in front of the class. Each correct answer will be marked and recorded by the lecturer. Table 4 below shows the average scores of each of the group assignments completed by the learning groups.

Table 4: The average scores of group assignments

SCORES	GROUP ASSIGNMENTS			
	1	**2**	**3**	**4**
MAX	18.0	30.0	13.0	17.5
MIN	17.0	18.0	9.5	0.0
AVG	17.9	29.4	12.8	16.0

From Table 4 above, it is shown that almost every question has been answered correctly by all learning groups. From the average scores depicted in Table 4, we can conclude that each of the group has shown high level of achievement in each of the programming questions given to them.

Finally, at the end of the semester, the students were asked to sit for the GALT test (post-test) again to determine whether or not their logical thinking levels have changed during the process of learning programming through cooperative learning. Table 5 below shows the differences of logical thinking levels where there was an increasing number of HLT among the students.

Table 5: Frequency of logical thinking levels among first semester students based from GALT post-test results

Logical Thinking	JUL-NOV 07	%	JUL-NOV 08	%
HLT	37	80.4%	42	82.4%
LLT	9	19.6%	9	17.6%
TOTAL	46	100.0%	51	100.0%

From Table 5, it shows that there are more than 80% of the students who were the HLT students at the end of each semester. This explains the changes of logical thinking levels among students from LLT to HLT throughout the process of learning programming in groups. This has proved that learning programming through cooperative learning will help the weaker learners be more motivated to accomplish the task with the help received from the more competent learners. From the interviews conducted to the students at the end of the semester, most of them agreed that their programming skills had improved by learning in groups. This supports the claimed made by Johnson et.al. (1995) where cooperative learning methods have proven effective in increasing motivation for learning and self-esteem, redirecting attributes for success and failure, fostering positive feelings towards classmates, increasing performances on tests of comprehension, reasoning and problem solving.

In the final phase of this study, a conceptual framework is being constructed to apply the cooperative learning technique in virtual environment. This idea is encouraged due to the fact that the in-class practice of cooperative learning method have shown a significant effect to the students' logical thinking levels. Therefore, the motivation is driven by the idea to exploit the use of information technologies and also to actively follow the rapid change in learning environment that nowadays is moving towards mobile and virtual learning.

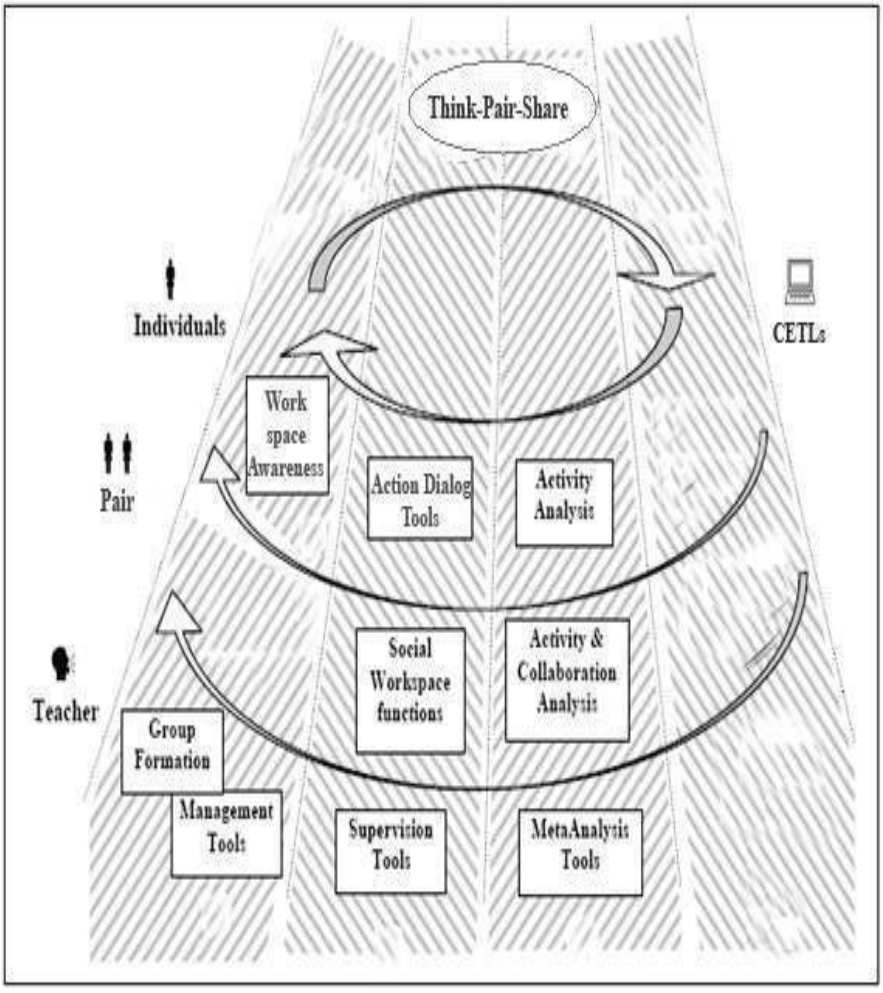

Figure 1: The Conceptual Framework of Online Collaborative Learning System

Figure 1 above depicts the conceptual framework of an online collaborative learning system using a cooperative learning technique known as Think-Pair-Share. This framework is adopted from Nik Azlina (2008) framework for developing the online collaborative system for Science subject. From this framework, we have developed a use-case diagram that illustrates the whole activities involved in the online collaborative learning system (Figure 2).

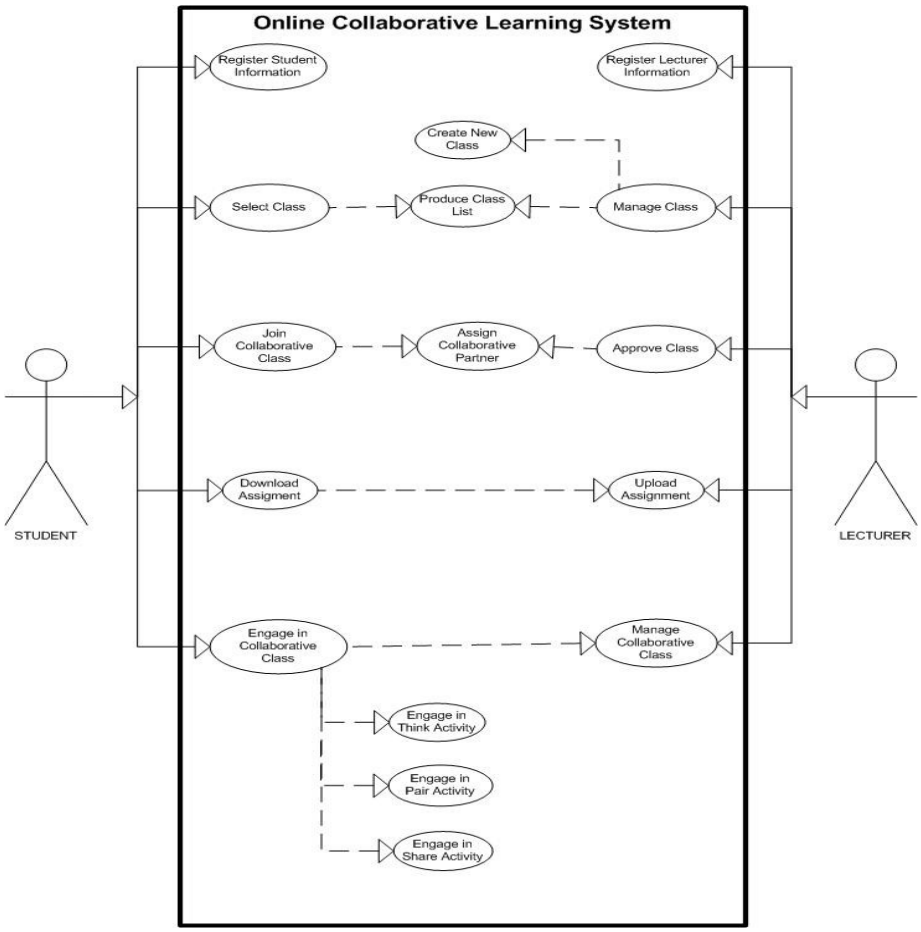

Figure 2: The Use-Case Diagram for Online Collaborative Learning System

From Figure 2, we can see that there are two actors that play the main role, which are the lecturer and the student. The lecturer will be able to manage the class, assign the collaborative partner, upload assignments and manage the collaborative class. The students in the other hand will involve in selecting their classes, join the collaborative classes, download the assignments and most importantly engage in collaborative activities which include three phases, Think-Pair and Share. Through this technique, firstly, a student must think first the possible answer, and then the student will discuss with his or her pair the answer that he or she has thought about. The pair needs to finish the task in a given period of time. Each student needs to discuss with their partner via the instant messaging system or a chat room. Later, after completing the task, they need to share their answers to the rest of the class where the answers can be published or downloaded thru the discussion board or email services. The teacher will then grade the answers and records the marks that the students have acquired.

Conclusion

From the discussion of this study, it can be concluded that the logical thinking levels among Computer Science students are vary from one and another. Realizing these differences of logical thinking levels and the crucial needs for the students to possess high logical thinking capabilities in programming courses, it is important for the educators to find the right approaches in order to improve the teaching and learning of computer programming as programming courses have often been portrayed as a difficult subject to study.

By conducting this study, it can be seen that cooperative is indeed a successful learning style in enhancing students' logical thinking levels in programming classes. The team effort as demanded in the Numbered Heads

Together technique implemented in this study will help to boost the students' self-esteems and can improve individual performance as they will learn that a team needs the effort from everybody in the group and that the group as a total is counting on each individual. Previous researches have proved that cooperative learning techniques promote student learning and academic achievement, increase student retention and promote student self-esteem.

Therefore, cooperative learning can be seen as a new method that can be incorporated in programming classes in order to achieve better results in programming courses. Although this paper do not discuss about the students' achievements in the programming course, however it has been widely claimed by researchers that with higher logical thinking levels, students will perform better in programming fields.

In the final part of this study, the online collaborative learning system was being designed and discussed. From the design of the conceptual framework, we can conclude that cooperative learning technique not only can be implemented in classes where physical interactions happen, but it is also can be implemented in a virtual environment. However, the technique of cooperative learning needs to be selected carefully as not many techniques can suit the virtual environment. Therefore, the potential technique which is the Think-Pair-Share technique has been selected as it has much lower risk and less complicated. However, further studies are remanded in this area as this proposed framework has not been fully completed and being tested to study their effectiveness towards students' logical thinking levels and performances in programming courses.

References

Ala-Mutka, K. (n.d.), *Problems in learning and teaching programming - a literature study for developing visualizations in the Codewitz-Minerva project*. Codewitz Needs Analysis. 1-12.

Albrecht,K. (1984). *Brain Building: Easy games to develop your problem solving skills*. USA: Prentice Hall.

Atherton, J. S. (2005). *Learning and Teaching: Piaget's developmental theory*. Retrieved August 28, 2008, from http://www.learningandteaching.info/learning/piaget.htm

Cooper, J. & Mueck, R. (1990). Student involvement in learning: Cooperative learning and college instruction. *Journal on Excellence in College Teaching, 1*(1), 68-76.

Gros, B., Guerra. V., and Sánchez, J. (2005). The Design of Computer-Supported Collaborative Learning Environments in Higher Education, *Encounters on Education, Volume 6, pp. 23 – 4*, University of Barcelona, Spain.

Mohd Nasir Ismail, Nor Azilah Ngah & Irfan Naufal Umar. (2006). Instructional strategy in the teaching of computer programming: What exactly is the problem? *Proceedings of The Malaysian Educational Technology Assocation (META) 19th Convention*, Awana Porto Malai, Langkawi, 9-11 September, 2006.

Johnson, D.R & Johnson R.T., (1995). *Learning together and alone (3rd ed.)*. Boston: Allyn & Bacon.

Kagan, S. (1989). The Structural Approach to Cooperative Learning. *Educational Leadership, 47* (4), 12-15.

Kagan, S. (1994). *Cooperative Learning.* San Juan Capistrano, CA: Kagan Cooperative Learning.

Kessler, C (1992). *Cooperative language learning: A teacher's resource book*. New Jersey: Prentice Hall Regents.

Lahtinen, E., Ala-Mutka, K., Jarvinen, H. (2005). A study of the difficulties of novice programmers. *ACM SIGCSE Bulletin*, 37(3), 13-14.

Malik, D.S. (2004). *C++ Programming: From Problem Analysis to Program Design.* USA: Thomson Course Technology.

Mahdizadeh, H. (2007). *Student Collaboration and Learning, Knowledge construction and*

participation in an asynchronous computer supported collaborative learning environment in higher education. PhD-thesis, Social Sciences Group, Wageningen University and Research Centre, The Netherlands.

Nik Azlina Nik Ahmad. (2008). *The Collaborative Teaching Environment System Using Think-Pair-Share Technique.* Masters thesis. University of Malaya.

Nunan, D. (1992). Introduction. *Collaborative language learning and teaching*. New York: Cambridge University Press.

Nsw.edu (2006). *Think-Pair-Share. New South Wales, Country Areas Program*. Retrieved August 18, 2009, from http://www.cap.nsw.edu.au/QI/TOOLS/stuv/thinkpairshare.htm

O'Malley, J. M. & Chamot, A. U. (1990). *Learning strategies in a second language acquisition.* Cambridge: Cambridge University Press.

Roadrangka, V., Yeany, R.H., & Padila, M.J. (1983). *The construction and validation of a group assessment of logical thinking (GALT).* Paper presented at the meeting of the National Association for Research in Science Teaching, Dallas, TX.

Sharan, S. *et al*. (1984). *Cooperative learning in the classroom:Research in desegregated schools*. Hillsdale, N.J.: Erlbaum.

Slavin, R. E. (1983). *Cooperative learning*. New York: Longman.

Slavin, R. E. (1995). *Cooperative learning: Theory, research and practice* (2nd ed.). Boston: Allyn & Bacon.

White, G.L. & Sivitanides, M.P. (2002). A Theory of the Relationships between Cognitive Requirements of Computer Programming Languages and Programmer's Cognitive Characteristics. *Journal of Information Systems Education , 13(1)*, 59-66.

Yaman, S. (2005). Effectiveness on Development of Logical Thinking Skills of Problem Based Learning Skills in Science Teaching, *Journal of Turkish Science Education*, 2(1), 31 – 33.

Zoran, M. (2008), *Logical thinking. Encyclopedia of Psychology.* Retrieved August 27, 2008, from http:// findarticles.com/p/articles/mi_g2699/is_0005/ai_2699000536/pg_2/