ONLINE COLLABORATION FOR PROGRAMMING: Assessing Students' Cognitive Abilities

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ABSTRACT

This study is primarily focused on assessing the students' logical thinking and cognitive levels in an online collaborative environment. The aim is to investigate whether the online collaboration has significant impact to the students' cognitive abilities. The assessment of the logical thinking involved the use of the online Group Assessment Logical Thinking (GALT) test that has been conducted in two phases; before and after the online collaborative activities.

The sample of respondents for this study is sixty first year Diploma in Computer Science students from Universiti Teknologi MARA (UiTM) Perlis, Malaysia where they were divided into fifteen collaborative groups. These collaborative groups were then engaged in a 3-hour session of collaborative activities via the Online Collaborative Learning System (OCLS). The results for this study has revealed that the online collaborative learning has significant impact to the students' logical thinking levels with the increment of 21.7% high logical thinkers with p-value<0.05 (sig. 2-tailed). Meanwhile, the investigation of the students' cognitive levels is being done by monitoring the students' abilities to solve the given questions via OCLS. The questions have been previously constructed according to the Bloom's taxonomy cognitive domain.

The results have also revealed that the students at the early stage of learning programming are able to solve complex programming problems at the cognitive level Application and Analysis. There was also a strong correlation between students' logical thinking skills with their abilities to solve problems in an online platform with r= 0.631, significant at 0.012.

Keywords: Online collaborative programming, logical thinking, cognitive levels

INTRODUCTION

The usage of information technology and communications these days have radically transformed the face of our education system especially in the area of flexible and distance learning. The mass used of online learning platforms is one of the evidences that show the rapid expansion of the Internet.

According to Tsai, Wu, Elston and Chen (2011), in this day and age, the Internet is not just purposeful for searching and surfing, but also has expanded to support varieties of educational activities including communication and online collaboration. Owen, Grant, Sayers and Facer (2006) have also acknowledged that the trends of e-learning styles have positively escalating towards the c-learning styles that emphasize the combinations of community, communicative and collaborative learning.

Collaborative learning has been famously implemented in the teaching and learning environment. Thus, the effectiveness of incorporating collaborative learning in physical classes has been proven and well-documented (Mahfudzah, Fazlin Marini, Khairunnisa, 2010). Although there are many ways to describe collaborative learning, the main purpose of implementing group collaboration is to bring the team together in order to accomplish a common goal (Mahfudzah, Muhaini, Fazlin Marini, 2013). This has also becomes the main purpose of many online collaborative platforms. Varieties of Web 2.0 tools have been used to facilitate communication, collaboration activities and problem-solving process over geographic distances and from dispersed locations.

In teaching and learning computer programming, there are numbers of online collaborative learning platforms that have been developed to support online collaboration. Codewitz, for instance, is a project that used web-based platform to support learning programming concepts using visualizations (Lahtinen, Ala-Mutka & Jarvinen, 2005). Meanwhile, Van Hiele Web-Based Learning System that was developed by Chen and Chih (2006) has also incorporated a range of Web 2.0 tools such as electronic mails, discussion board, assignment and tutorial modules and knowledge management.

Other than that, Cavus (2007) have also developed a Learning Management System using Moodle LMS with the combination of collaborative learning tool called GREWPtool to support a virtual teaching environment for learning programming languages. Current researches involve more complex and highly interactive systems such as the Online Collaborative Learning System (OCLS) designed by Mahfudzah, et. al (2013), Programming Assignment aSsessment System (PASS) by Law, Lee, and Yu (2010), Supporting Collaboration and Adaptation in a Learning Environment (SCALE) by Verginis, Gogoulou, Gouli, Boubouka and Grigoriadou (2011) and AutoLEP by Wang, Su, Ma, Wang and Wang (2011).

Many of these online collaborative platforms are being developed not only to support the teaching and learning of computer programming, but also to enhance the students' performance, improve their learning styles as well as their problem-solving skills. For example, by using SCALE, the students are expected to actively participate with their own progress in programming by referring to the information and feedbacks given by the system. Through this, students will become increasingly aware of their own performance in programming courses (Verginis, et.al, 2011).

Meanwhile, by using PASS, the well facilitated e-learning environment in this system is claimed to be advantageous in motivating students' learning process and activities (Law, et.al, 2010). Besides that, the used of OCLS has been proven to give positive impact towards students' performance where the t-test analysis had showed significant value of 0.01, which is less than 0.05 (sig. 2-tailed) (Mahfudzah, et.al, 2013). Previously, AutoLEP, which is specifically designed to assist novice programmers in mastering their programming skills, has been proven effective in improving students' learning experience hence effectively ease the workload of the instructors (Wang, et.al, 2011). Other research claimed that by utilizing the collaborative e-learning systems in teaching and learning programming, it has positively improved the interactions and participation among the students and the tutors as well as successfully facilitated real-time compilation of activities for the students (Cheung, 2006).

While there are a lot of online collaborative systems developed over the years to support the teaching and learning of computer programming courses, whilst the implementation has also been proven effective, however, there is still lack of study that focus on how the online collaborative system can effectively influences the students' cognitive abilities in programming. Previous studies have emphasized that cognitive abilities are crucial for the students to master in programming. White and Sivitanides (2002) claimed that cognitive abilities are one of the factors that determine the success in computer programming courses. Among the cognitive abilities needed to become an expert programmer as highlighted by Mohd Nasir, Nor Azilah and Irfan Naufal (2006) are analytic processing, problem-solving skills, reasoning and logical thinking skills as well as mathematical skills.

Mahfudzah, et. al. (2010) have also claimed that logical thinking skills are one of the important factors that determine the students' abilities to analyze, plan and solve problems in programming. According to Piagetian theory, there are four stages of cognitive development comprises of sensory-motor, pre-operational, concrete operational and formal operational where the ability to think logically is determined in the period of abstract process and has been claimed as the higher cognitive skill (Atherton, 2005). Learners will use their logical thinking skills to solve problems by engaging in varieties of mental practices or by doing some abstraction and generalization (Yaman, 2005).

In order to measure the level of logical thinking skills, the Group Assessment Logical Thinking (GALT) test can be utilized as the measuring tool (Tuna, Biber & İncikapı, 2013; Lay, 2009; McConnell, Steer, Owens & Knight, 2005; Yaman, 2005). The GALT test was developed by Roadrangka, Yeany and Padila (1983) and they have identified six logical subscales which are conservational reasoning, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning and combinatorial reasoning. Therefore, the lack of study that focus on the assessment of the students' cognitive abilities especially in their logical thinking and cognitive skills in an online collaborative environment has raised the research questions for this study; i) how can we measure the students' logical thinking and cognitive levels?, ii) do the online collaborative activities significantly affect the students' logical thinking levels?, iii) do the students' logical thinking skills have any correlation with their abilities to solve questions collaboratively in an online platform? Therefore, this study is aimed to investigate the students' logical thinking levels before and after they engage in the online collaborative activities. This is to assess whether the online collaboration has significant impact on their logical thinking skills or otherwise. Apart from that, this study will also measure the students' cognitive levels based from the questions posted online. Each question represents different cognitive levels where the collaborative groups will be asked to solve the questions collaboratively in an online collaborative environment. In this study, the Online Collaborative Learning System (OCLS) will be used to facilitate the online collaboration.

MATERIALS & METHODS

The research method for this study is divided into four main phases as mentioned below:

Research Populations and Sample

The population of this study was the students enrolled in Diploma in Computer Science from Universiti Teknologi MARA (UiTM) Perlis, Malaysia. The sample of the respondents was sixty male and female students from the first year of the particular program. Prior to this, fundamentals programming course has been taught to these sample groups for the period of four months, meaning that, they have already had prior knowledge in basic programming

concepts. Before this research was conducted, collaborative activities have not been implemented either in the classrooms or via online platforms.

Pre-Logical Thinking Test

A week before they attended the online collaborative session, the sample groups were asked to answer an online logical thinking test. The online logical thinking test used in this research was an electronic version of a pen and paper based GALT test that has been widely used to measure logical thinking levels in the field of education. The Cronbach's alpha reliability coefficient of the logical thinking test was recorded at 0.52 which is considered moderate for use in the study (Lay, 2009). The GALT test used in this study consists of twelve items and ranging from six subscale measures for logical operations as highlighted by Roadrangka, et.al (1983). The subscale measurement as stated in the Table 1 below reflected the Piagetian cognitive reasoning abilities modes.

Table: 1
The six subscale measures for logical operations in GALT test

Subscales	Item No.	Item Descriptor
Conservational reasoning	1	Piece of Clay
	2	Metal Weigh
Proportional reasoning	3	Glass Size
	4	Scale
Controlling variables	5	Pendulum Length
	6	Ball
Probabilistic reasoning	7	Square and Diamonds #1
	8	Square and Diamonds #2
Correlational reasoning	9	The Mice
	10	The Fish
Combinatorial reasoning	11	The Dance
	12	The Shopping Center

The pre-logical thinking test results were then assessed where the students who were able to answer more than six items correctly were categorized as high logical thinkers (HLT), while the others with scores lower than six were categorized as low logical thinkers (LLT). These scores were recorded and used to divide the students into fifteen collaborative groups. Each collaborative group consists of a mixture of HLT and LLT students.

Online Collaborative Activities

The collaborative groups were then asked to engage in the collaborative activities in the online collaborative system. As mentioned before, in this study, the Online Collaborative Learning System (OCLS) will be used to facilitate the online collaboration. Figure 1 below depicts some of the user interfaces of OCLS where the collaborative groups used to engage in the online collaborative activities. The details of the system's development and architecture have been discussed by Mahfudzah et.al. (2013).

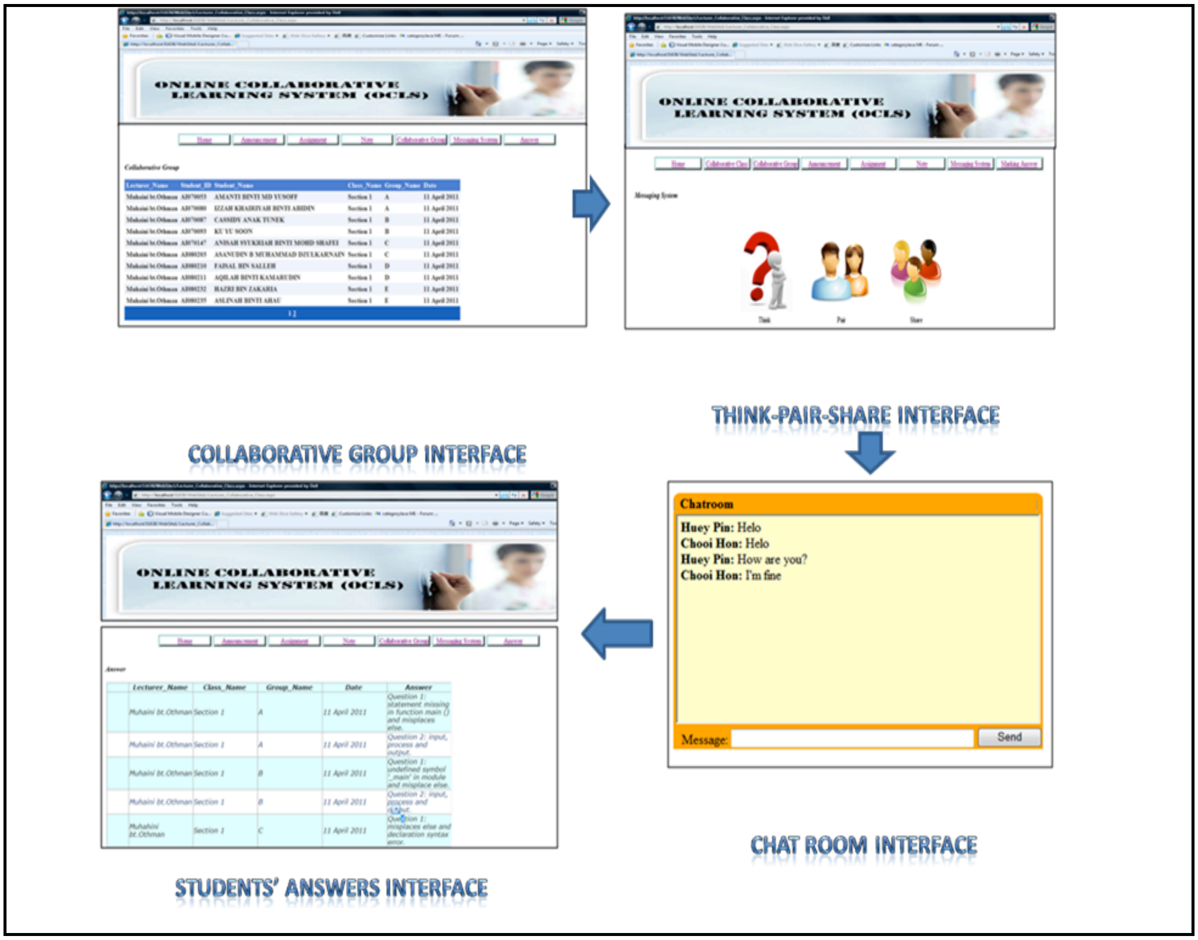

Figure: 1
OCLS's user interface that support online collaborative activities Mahfudzah et.al. (2013)

Via OCLS, the questions were posted by the lecturers and the collaborative groups were asked to provide the solutions in a 3-hours online collaborative session. The questions given to the collaborative groups were developed by the lecturers with more than seven years teaching experience in programming. The questions were constructed based from the Fundamentals of Computer Problem-Solving course which comprises six sub topics with different cognitive levels.

In this case, the Bloom's taxonomy cognitive domain which has six stages; knowledge (C1), comprehension (C2), application (C3), analysis (C4), synthesis (C5) and evaluation (C6) was used as the guideline in the construction of the questions.

Table: 2 lists the distribution of questions that were used in this study.

Table: 2
The distribution of questions constructed according to the Bloom's taxonomy cognitive domain

Question No	Name Of Question	Topic Covered	Chapter	Cognitive Level	Marks
Q1	Working Hours	Sequential	2	C3-Application	6
Q2	Calculate the Income	Selection	3	C4 - Analysis	17
Q3	Prime Number	Repetition	4	C4 - Analysis	8
Q4	Rectangle	Repetition	4	C4 - Analysis	5
Q5	Diamond Shape	Repetition	4	C5 - Synthesis	10
Q6	Pantun	Selection	3	C6 - Evaluation	20
Q7	The Tallest Student	Functions	5	C4 - Analysis	10
Q8	Odd Numbers	Arrays	6	C4 - Analysis	12

According to Table 2, eight questions have been given to the collaborative groups ranging from the application (C3) stage until the higher order thinking skills which were synthesis (C5) and evaluation (C6).

This was because the lecturers were taking into accounts the students' previous learning experience in the fundamentals of computer programming paper. The online collaborative session was done in a controlled 3-hour session with the lecturers giving feedbacks and results promptly.

This was to encourage the collaborative groups to engage in a more interactive, communicative and collaborative online learning environment.

Post-Logical Thinking Test

After the 3-hour session has ended, the students were again asked to take the online GALT test in order to investigate the improvements to the students' logical thinking levels after the online collaborative activities.

The post-logical thinking test results were also assessed and recorded. Later, both the pre-test and post-test logical thinking scores were being analyzed using IBM SPSS Statistics 19.0.

Types of analysis used in this study are descriptive analysis and paired-samples t-test to find the significant impact of online collaboration towards students' logical thinking abilities and Spearman Rho's Bivariate correlations to find the correlations between the students' logical thinking levels and their abilities to solve programming questions in an online platform.

RESULTS & DISCUSSIONS

Students' Logical Thinking Assessments

As mentioned in the previous section, the sample groups were asked to answer the pre and post-logical thinking test using the online GALT test.

The pre-logical thinking test was taken a week before the sample groups engage in the online collaborative activities. Table: 3 below depict the results of pre-logical thinking tests for all sixty students.

Table: 3
Pre-logical thinking test's results for all students

		Frequency	Percent	Valid Percent	Cumulative Percen t
Question	1	1	1.7	1.7	1.7
	2	6	10.0	10.0	11.7
	3	18	30.0	30.0	41.7
	4	5	8.3	8.3	50.0
	5	12	20.0	20.0	70.0
	6	11	18.3	18.3	88.3
	7	5	8.3	8.3	96.7
	8	1	1.7	1.7	98.3
	9	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

From the results in Table 3, it shows that about 42 students (70%) have scored 5 marks and below, which made them low level thinkers (LLT). Meanwhile, only 18 of the students (30%) have scored more than 6 marks, which identified them as high logical thinkers (HLT).

Moreover, there was only one student who was able to answer up to nine questions correctly and none of the students have scored a full twelve marks in the pre-logical thinking test.

The mean score for this test is 4.42 which described that the overall score of the logical thinking abilities among the students were relatively low.

These pre-logical thinking marks were then used to divide the students into fifteen small collaborative groups where each group consists of four members from the mixture of LLT and HLT.

Table: 4 display the distribution of the collaborative groups (labeled as G1 until G15) with their mean logical thinking scores were between 4.25 until 4.50.

Table: 4
The pre-logical thinking's mean scores for each collaborative group

NO	GROUP	Pre-Logical Thinking Mean Score
1	G1	4.25
2	G2	4.50
3	G3	4.50
4	G4	4.25
5	G5	4.50
6	G6	4.25
7	G7	4.50
8	G8	4.50
9	G9	4.25
10	G10	4.50
11	G11	4.25
12	G12	4.50
13	G13	4.50
14	G14	4.50
15	G15	4.50

Meanwhile, Table: 5 shows the results for the post-logical thinking test. As explained previously, the post-logical thinking test was taken after the collaborative groups engaged in a 3-hour session of online collaborative activities via OCLS.

The aim was to assess whether the students' logical thinking levels have increased after the online collaboration session.

From the analysis revealed in Table 5, the results have showed an increment of HLT where the number of students who scored more than 5 marks have increased to 31 students (51.7%). Thus, adding 13 more students in the HLT's group with 21.7% increment.

Meanwhile, the other 29 students have remained as LLT (48.3%). The results have also showed that at least one student was able to answer more than ten questions in the post-logical thinking test.

However, none of them were able to answer all twelve questions correctly. The mean score for the post-logical thinking test is 5.20 which showed slight increment from the pre-logical thinking's mean score.

Table: 5
The post-logical thinking results for all students

		Frequency	Percent	Valid Percent	Cumulative Percent
Question	2	5	8.3	8.3	8.3
	3	11	18.3	18.3	26.7
	4	2	3.3	3.3	30.0
	5	11	18.3	18.3	48.3
	6	18	30.0	30.0	78.3
	7	9	15.0	15.0	93.3
	8	2	3.3	3.3	96.7
	9	1	1.7	1.7	98.3
	10	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

Table: 6 below depict the post-logical thinking mean scores for the fifteen collaborative groups after the online collaborative activities. The results have exhibited that all fifteen collaborative groups have showed an increment in their mean scores between 4.50 until 6.25.

Table: 6
The post-logical thinking's mean scores for each collaborative group

NO	GROUP	Post - Mean Score
1	G1	4.50
2	G2	5.25
3	G3	5.00
4	G4	5.00
5	G5	5.25
6	G6	5.50
7	G7	5.00
8	G8	5.25
9	G9	5.00
10	G10	6.25
11	G11	4.75
12	G12	5.25
13	G13	5.50
14	G14	5.50
15	G15	5.00

For further investigation, a paired-sample t-test was conducted in order to investigate the significant impact on students' logical thinking levels after the online collaborative activities. Table 7 below reveals that on average, all fifteen collaborative groups have increased their logical thinking abilities with mean score of 3.133 and statistic test (t) result is +8.951, with the p-value<0.05 (sig. 2-tailed).

Table 7: The paired-samples t-test result

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Post mean score-Pre mean score	3.133	1.356	.350	2.383	3.884	8.951	14	.000

Therefore, based from all of these analyses, it has been proven that the online collaborative activities designed and implemented for this study specifically for teaching and learning programming, have significant impact on the students' logical thinking levels.

Students' Cognitive Levels Based from the Questions They have Solved

Table: 8 below display the distribution of questions that the collaborative groups have answered via OCLS. Previously, the questions developed for this study have been constructed based on the Bloom's taxonomy cognitive domain.

Table: 8
The questions that have been answered by the collaborative groups

	Q1 (C3)	Q2 (C4)	Q3 (C4)	Q4 (C4)	Q5 (C5)	Q6 (C6	Q7 (C4)	Q8 (C4)
Mean	1.00	.53	.20	.20	.13	.00	.53	.20
Std. Deviation	.000	.516	.414	.414	.352	.000	.516	.414
Variance	.000	.267	.171	.171	.124	.000	.267	.171
Sum	15	8	3	3	2	0	8	3

By referring to Table 8, it shows that all fifteen collaborative groups were able to solved question Q1 that covers the topic sequential control structure with cognitive level C3 (application). Meanwhile, eight collaborative groups were able to answer question Q2 (selection control structure) and Q7 (functions) successfully, with both questions constructed for cognitive level C4 (analysis). However, only three groups were able to solved questions Q3, Q4 and Q8 where each question represents topics from repetition control structure and arrays. All three questions are designed to conform to level C4 (analysis) in Bloom's taxonomy cognitive domain. From the findings of this study, it has also revealed that questions with higher order thinking skills which are question Q5 and Q6 with cognitive level C5 (synthesis) and C6 (evaluation) were considered hard for the students to solve where none of the collaborative groups were able to successfully solved question Q6 even though the question was also constructed under the topic selection control structure.

Correlations between Collaborative Groups' Logical Thinking Mean Scores with Their Abilities to Collaboratively Solve Questions in an Online Environment

In–depth investigation has also revealed the significant correlation between the collaborative groups' logical thinking mean scores with their abilities to solve the given questions in an online environment. Table 9 below exhibits the Spearman's Rho Bivariate correlations analysis that shows strong correlation with r= 0.631, at the rate of 39.8% and significant value is 0.012, which is less than 0.05 (sig. 2-tailed). This analysis has proved that the logical thinking ability is one of the important factors that determine the students' success rates in solving computer programming questions in an online collaborative environment.

Table: 9
Correlations between collaborative groups' logical thinking mean scores with their abilities to solve questions in OCLS

			Collaborative groups' mean score	Ability to solve questions
Spearman's rho	Collaborative groups' mean score	Correlation Coefficient	1.000	.631**
		Sig. (2-tailed)	.	.012
		N	15	15
	Ability to solve questions	Correlation Coefficient	.631**	1.000
		Sig. (2-tailed)	.012	.
		N	15	15

CONCLUSION

Online collaborative system for teaching and learning programming has been widely developed and implemented; hence provide many benefits to the students and the lecturers as well. Among the advantages that have been claimed by many researchers are the online collaboration is able to improve students' interaction and participation in the online environment, aids novice programmers in improving their programming skills and also improve students' learning styles and performance.

In this study, a series of assessments have been conducted in order to investigate whether the online collaboration for teaching and learning programming course have positively affect the students' cognitive abilities or otherwise. From the findings of this study, it has revealed that with proper cognitive assessments, group's formulation and construction of questions; the online collaborative activities seemed to give significant impact to the students' cognitive abilities especially in their logical thinking skills.

Besides that, through this study, the researchers have realized that the students at their early stage of learning programming were able to solve programming questions with cognitive levels as high as application and analysis; taking into considerations few factors such as the questions are carefully constructed based from the Bloom's taxonomy cognitive domain by experienced lecturers and the students' previous knowledge in fundamentals programming concepts.

Although the results have showed positive effects towards students' cognitive abilities, further investigation need to be conducted by looking into other factors that could contribute

to the success of online collaboration for teaching and learning programming such as providing the online collaborative system with learner models for personal reflections, online feedbacks for students' performance or other types of assessments such as online peer and expert evaluations.

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