The Impact of Inquiry-based Integrated STEM on Student's Perception of Learning Science and Computer Programming

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Abstract: The study proposed an inquiry-based integrated STEM activity to guide students in game design and investigated its impact on student's perceptions of learning science and computer programming. The participants were 49 university students who participated in Web game design programming course. The results showed that the activity reduced students' conception of test-to-learn, and enhanced their surface and deep learning motivation and deep strategy in learning science. Moreover, students perceived a higher computer programming self-efficacy in terms of logical thinking, algorithm, debug, and cooperation. The findings of the study provide practical suggestions for the guildance of game design.

Keywords: Integrated STEM, inquiry-based learning, learning science, computer programming

1. Introduction

Recently, STEM education has been extensively implemented in educational contexts to foster various competencies such as 21st century competence, problem-solving literacy, and computer programming (Chen et al., 2019). STEM education, where students are required to use two or more than disciplines to create solutions or productions, allows students to organize and apply STEM knowledge and develop STEM skills by experience the design process. Many studies have proposed various STEM activities, such as robot design and making game (Newton, Leonard, Buss, Wright & Barnes-Johnson, 2020). Such a learning process contributes to the integration of disciplines knowledge and the development of technology and engineering competencies.

Although literature on game design presents the benefit on teaching and learning, it is hard for students to effectively apply STEM disciplines to make a game. It requires not only programming competence, but also physics, mathematics, and engineering competencies. Previous studies pointed out that students have difficulties in connecting concepts across disciplines and effectively integrating disciplines knowledge in STEM activity (Kelley & Knowles, 2016). Therefore, some students frequently failed in creation of artifacts and disinterested in science and mathematics (Thomas & Watters, 2015). Hence, it is necessary to provide instructional support for students in applying science and mathematics in technology and engineering.

5E model proposed by Bybee (1997) may be a potential approach to solving aforementioned problems since it helps students refine their initial concepts and establish connection between disciplines and reality by practical experience. The 5E model consists of engagement, exploration, explanation, elaboration and evaluation phases. Previous studies have showed the benefit of the 5E model on learning motivation and performance (Chen et al., 2019) because the model strengthened students' understanding and application of concepts to solve complex problems (Fadzli et al., 2020). Hence, this study designed an inquiry-based integrated STEM activity to guide students in game design and investigated its impact on student's perceptions of learning science and computer programming.

2. Method

2.1 Participants

A one-group pretest-posttest design was conducted in the study to investigate the effect of the inquiry-based integrated STEM activity on learning game design. The participants of this study were 49 university students who aged from 19 to 21 years old. The participants consisted of 25 females and 24 males. Before the class, they had learned basic Web programming concept last semester. However, they had no experience of designing game that required to integrate science, technology, mathematics, and programming. The participants were divided into 12 groups of four to five to participate in the inquiry-based integrated STEM activity and finally collaboratively designed a game.

2.2 Procedure

The pre- and post- questionnaires including conception of and approaches to learning science, and computer programming self-efficacy were implemented for 30 minutes before and after inquiry-based integrated STEM activity. The activity was implemented two sessions (150 mins) per week in six weeks, which guided students how STEM knowledge was applied to develop a game. In the 1st session, a designed action game was demonstrated and introduced basic concept and roles of each discipline. In the 2nd session, the activity provided students with the five inquiry phases based on 5E inquiry model (Bybee, 1997) to guide them in exploring the relationships among STEM disciplines. Moreover, students were required to apply knowledge and competencies they learned to complete the assigned task. Finally, whole-class discussion was conducted to reflect learning process and gave them feedback. Such an inquiry model was repeatedly implemented in different topics such as horizontal, vertical, and projectile motion. After the activity, each group needed to jointly design a game that required to integrate STEM disciplines and shared their game with whole class.

2.3 Data Collection and Analysis

The conceptions of learning science (COLS) and approaches to learning science (ALS) questionnaires developed by Lee, Johanson, and Tsai (2008) were applied to investigate students' perceptions of learning science before and after the activity. In addition, the computer programming self-efficacy scale (CPSES) (Tsai, Wang, & Hsu, 2018) was used to measure their perceptions of computer programming learning. The overall Cronbach alpha values of the questionnaires are .92, .84, and .95, respectively, indicating that the questionnaires were adequately reliable. The feedback of the questionnaires was analyzed by a paired t-test to understand the effect of the activity on learning game design.

3. Results

Table 1 shows the results of student's pre- and post- COLS questionnaire. The students perceived a significantly lower level of test-to-learn concept after the activity than they did before the activity (t= 2.73, p<0.01). However, no significant difference was found in the others dimensions. The results indicated that the activity may improve students' learning science for testing. Table 1 displays that students held a significantly higher level of deep (t=-4.01, p<.00) and surface motivation (t=-3.06, p<.01), and applied deeper strategy (t=-4.36, p<.00) after the activity than they did before the activity. The results suggested that the activity may contribute to not only the enhancement of students' deep motivation strategy but also their surface motivation.

Table 1. *The Result of Students' COLS And ALS Before and After the Inquiry-Based Integrated STEM Activity*

Questionnaires	Dimensions	Pre		Post		*t*	*p*
		Mean	SD	Mean	SD		
COLS	Memorizing	3.56	.72	3.43	.68	1.26	.21

	Testing	3.47	.97	3.15	.89	2.73**	.00
	Calculating	3.62	.80	3.52	.60	.97	.33
	Increasing	3.80	.63	3.71	.76	.82	.42
	Applying	3.53	.94	3.56	.81	-.23	.82
	understanding	3.72	.89	3.64	.76	.71	.48
	Seeing	3.77	.89	3.71	.78	.40	.69
ALS	Deep Motivation	2.56	.72	2.95	.72	-4.01***	.00
	Deep Strategy	2.88	.77	3.32	.77	-4.36***	.00
	Surface Motivation	3.33	.81	3.65	.69	-3.06**	.00
	Surface Strategy	3.33	.83	3.21	.82	1.09	.28

*p<.05, ** p <.01, *** p <.001

Table 2 reveals that significant differences were found in the dimensions of logical thinking (t=-3.16, p<.01), algorithm (t=-2.66, p<.05), debug (t=-3.6., p<.001), and cooperation (t=-3.29, p<.01) except for the dimension of control (t=-.81, p>.05). The results indicated that the students perceived their computer programming skills activity may be a potential approach to increasing students' computer programming skills.

Table 2. *The Result of Students' CPSES Before and After the Inquiry-Based Integrated STEM Activity*

	Pre		Post		*t*	*p*
	Mean	SD	Mean	SD		
Logical thinking	4.30	1.15	4.80	1.09	-3.16**	.00
Algorithm	3.36	1.18	3.84	1.30	-2.66*	.01
Debug	3.73	1.18	4.35	1.12	-3.60***	.00
Control	4.82	1.10	4.95	.98	-.81	.42
Cooperation	4.17	1.03	4.64	.94	-3.29**	.00

*p<.05, ** p <.01, *** p <.001

4. Conclusion

The study proposed an inquiry-based integrated STEM activity for facilitating students in game design. The results showed that students held a lower level of using test-to-learn concept when participating in the activity. In the other hands, students perceived higher level of deep motivation and strategy, as well as surface motivation. The results suggested that integrated STEM activity with inquiry learning may be an effective approach to enhancing student's learning strategy and motivation, and increasing computer programming skills. However, it is noted that the improvement of conceptions of learning science was not found. It may be due to the fact that they had learned the science concepts involved in the activity. Further study should be conducted with quasi-experimental design to verify the findings of the study.

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