Using Digital Game as Compiler to Motivate C Programming Language Learning in Higher Education

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***Abstract* — In recent years, teaching and learning process for all educational levels has been reformed in order to rapid growth of technological learning and a variety of tools. Educational computer game, which is one of effective tools, has been used for supporting teaching and learning in various subjects. Therefore, this study developed digital game named CPGame for simulating the compiler working with situation in human daily life in C programming language learning. The developed game was implemented with fifty-university learners to evaluate whether and how the learners with different achieving levels are motivated to learn C programming language through playing the C programming game. The experimental data was analyzed by using MANOVA and found that both high- and low-achieving learners are motivated to learn the topic through the developed game.**

Keywords—educational game; individual differences; computer science education; higher education

I. INTRODUCTION

The teaching and learning process in the 21st century has been reformed to creative and innovative learning environment. The technological tools have been used for supporting learning in various subjects for different educational levels [1,2]. Regarding the field of information and communication technology, computer science, and related fields, the principle skill as programming concept is very important. It is related to the fundamental programming construct and the algorithm problem solving [3]. In general, learners believe that it is a difficult subject since they have more experience in the graphic environment more than text-based editor, which is normally used for developing the program [4]. Besides, the logical thinking is extremely required in the computer-programming subject because the learners have to analyze the problem then design and conceptualize their idea into the algorithm before developing and constructing programs. Therefore, novice learners have faced with various difficulties in computer programming [5]. Moreover, the computer-programming subject normally has a high dropout and failure rate since various factors such as the complexity and technical nature of subject, the possible lack of logical problem solving skill, and the language problem [3].

To address above issues, several researchers suggested that edutainment technologies, especially educational computer games with interactive procedures, could enhance learners' logical thinking. Because the games inspired the learners to expand their knowledge [6]. In other words, the learners should be encouraged to study the computer-programming concepts in an entertaining platform, which is enable them to shift their learning outcomes from the uninterested environment into learning programming matter [6]. The game also promoted the learners' intrinsic motivation because it consists of six attributes including fantasy, challenge, competition, curiosity, control and recognition [7]. Moreover, the educational computer game affected learners in three main areas, such as learners' acceptance, entertainment, and emotion leading to encouraging learning performance [8]. Obviously, in previous studies, the use of games for promoting learners' motivations and supporting their learning performance has been thoroughly explored. Nevertheless, how the learners with different achieving levels are motivated to learn through playing and learning games has not been well addressed yet.

Based on the aforementioned issues, this study aims to shed light in this uninvestigated area. The first step of this work is to develop digital game named C programming (hereinafter CPGame) for simulating the compiler working with situation in human daily life in C programming language learning. This study then focuses on the main research question: Are there achieving levels, which promote learners' motivations, better regarding the game?

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II. RELATE RESEARCH

The concept of study is constructed from various researches and theories in order to present the idea for developing the CPGame. The main idea is classified by employing four main related research as follows:

A. Teaching and Learning in C Programming Language

In the last decade, the traditional educational methods rely on knowledge acquired from books and teachers [9]. While these day, the educational trend has been involved the technological media with more social learning approaches which are supported by the use of computers and communication technologies. For example, learning management systems such as Moodle, Blackboard have been used to support the basic need of higher education teaching [2]. Besides, Tan's research [10] which regarding the programming learning in higher education mentioned that both lecturer and learner consider it is a difficult subject. Face-to-face learning could not support effective teaching or achievement of learners in the topic. To solve learning difficulty, information technologies has been required to improve the level of learners' understanding since it gives appropriate feedback while working on programming such as online programming systems, web-based programming tutors, or online learning systems.

In recent years, a various variety of tools are available for supporting learners with learning and applying programming such as games, tools for solving problems, and computer simulations. Furthermore, mobile computer has gradually combined into educational contexts. It has been used to support traditional learning since it could promote innovative teaching methods such as cooperative learning, learning outside the classroom, and game-based learning [11]. Moreover, several research suggested that game is one of popular tools, which plays a big role in any field of education and level. According to Hainey's [7], Braghirolli's [12], and Dorji's [13] research, they mentioned that the use of educational computer game enhanced learners' motivations and learning achievement when compare with traditional teaching.

B. Educational Game and Learning Performance

According to Anissa's [14] research, it presented that the digital games covering several types and fields could be played by using the digital technologies such as computer, console, and mobile device. Digital game-based learning (DGBL) could fulfill the educational goal since it could motivate the learners via entertainment. In particular, DGBL could build-up a balance between learning and gaming elements in which it could produce two main significant foundations including educational and entertainment mechanisms. Therefore, many lecturers have relied on the DGBL to support their own teaching to benefit both learning and motivation advantages.

Besides, Braghirolli's [12] research, it declared that the educational game should be employed by concerning with behavioral concept and the learning process as an associative procedure. This then could cause a major role in changing observed behavior. This novel concept of learning was established by gamers looking for exercising concepts and/or abilities toward repetitive practice. However, games basing on constructivist conceptions should be focused on various aspects by concerning the importance of practical and experience in the construction of knowledge. Furthermore, Dorji's research [13] presented about the use of educational computer game increased motivations and better learning achievement. The positive impact was well received as new approach in teaching. Playing educational computer game for long-term had a positive effect on learners' learning abilities and construct knowledge because it has effects on cognitive development through visual skills including spatial representation, iconic skill, and visual attention.

Therefore, using the education computer game might support the programming learning performance because it prepares a virtual programming environment. A visual programming environment has the potential to support problem solving because it provided graphical elements representing problems or program states for a novice to comprehend a problem and assess the current program state [15].

C. Educational Computer Game and Motivation to Learn

According to Zainal's [16] research, it was found that motivations affected the learners' attitudes, implying that the motivated learners were more likely to change their attitudes to be more positive. Regarding programing subject, positive attitudes means studying hard and undertaking without giving up. In this case, learners were more motivated and stay motivated by intrinsic rewards, such as helpful criticism rather than extrinsic rewards such as good results. The study confirmed that the intrinsic rewards allowed the learners to be more satisfied than the extrinsic rewards. Besides, Glynn [17] asserted that the validation of science motivation of learners could be categorized into five items as follows: Intrinsic motivation relying on asking about interesting, curious, relevant, meaningful and enjoyable; Self-determination motivation relying on asking how hard to learn, to prepare well, to enough effort, to spend time and to use strategies; Self-efficiency motivation relying on how to earn good score, confident to do test, earn knowledge, understand and confident to do project; Career motivation relying on how to get a good job, promoted in career, career advantage, use knowledge in career and career relating; and Grade motivation focusing on asking about scoring, high grade, grade concern, grade's important and better

Furthermore, Hainey's research [7] suggested that game could affect the learners' motivation because the game contains six attributes, such as challenge: creating the competition; fantasy: creating the imagination related to responsibilities; control: creating power effecting on people's behavior; curiosity: creating a strong desire to learn; competition: creating the activity of competing; and recognition: creating the action of recognizing. In other words, Dorji et al.'s research [13] mentioned that an educational computer game was a good tool to promote learners participation in learning activities and then to motivate them in

their learning as it encourages learning within enjoyable environment. It showed more impact in promoting motivation in learning than conventional chalk and talk method. Moreover, it has been employed to motivate learners to take responsibility for their own learning leading to intrinsic motivation.

III. CPGame Conception and Features

A. CPGame Conceptions

Based on the previous studies using game for computer programming, it is considered that learners could understand and design the process of their logical thinking. It would be a good idea to develop the computer game to be a tool for supporting learning in computer programming subjects. It is expected to create an effectiveness by allowing the learners to practice their logic thinking as well as to learn the logic of programing design throughout the process of playing the game.

In this study, CPGame has been designed and developed for beginner of C programming language. This might motivate learners to change their idea of the difficult subject to be the interested learning. It has been used to support learners to learn and understand by themselves. Besides, enabling them to design algorithm, creating program, and debugging in basic C programming language could be achieved easily. The game focused on the contents related to programing development by using the game as a medium. The objective of the game is to help the learners to observe and compare the steps of the computer processing system (compiler) with real action. Moreover, it could support the learners to know and understand the errors of their program design and can finally correct it.

Moreover, contents inside the CPGame is related to fundamental computer-programming course, which is the first subject for learners who begin to understand the programming. In this study, the CPGame has been developed to support learners understand the basic C programming language in sequence structure; it is the basic and not complex format of programming by writing the command step-by-step. The CPGame has been designed in the manner of accumulated knowledge covering declaring variable, defining input, creating expression, and showing output in which knowledge gained from previous problem will be used in the next problems. Therefore, the difficulty of the game would gradually increase from easy to more difficult. Based on the designed story, it would be constructed by having a feature in which it keep players interested and make them want to solve the next problem.

B. CPGame Features

The CPGame has been a tool, which simulates the basic of C programming language. It has been designed to change the code editor format to be the real events game by trying to present the compiler working steps. It has been developed to support learners understand better than reading error message from existing editors. Regarding playing this game in each content, a player are asked to allocate code block for solving the problem followed by the requirement. The code block order will determine the game's event followed by the table of comparing between compiler working and game activity as shown in Table I. Each main event of game activity has been designed to have a similar function and error arising from the compiler through the components in the game. Fig. 1 represents the layout of the CPGame consisting of four parts. Firstly, the timer is used to show how many minutes left. The allocate code blocks area is allowed learners to allocate the code blocks follow by their algorithm. The group of code blocks area consists of function, operator, symbol and text. Lastly, the code block depending on the group of code blocks shows the number of each code block for guiding learners how many times they have to use it. After learners feel confident with their proposing code blocks, they can click 'Next' button for checking their code in the game scenario. It has been designed according to Table I. The game activity will present the step-by- step process followed by learners' code block.

TABLE I. Example of Compiler Working and Game Activity

Code Block	Compiler Action	Compiler Error	CPGame Activity Action	CPGame Activity Error
scanf	Receive input from user	Not show an error but the program cannot gets the value	Staff shows the barcode reader	Staff says "The barcode reader has problem"
(	Begin of scanf function	[Error] expected statement before ')' token	None	Monitor shows message "Something wrong about command system"
"	Begin of declare the conversion specifier	[Error] missing terminating " character	None	Monitor shows message "Something wrong about command system"
%f	The conversion specifier argument	Not show an error but the program cannot gets the value	Monitor shows message "Price is 0.00"	Monitor shows message "Can't show the price number"
"	End of declare the conversion specifier	[Error] missing terminating " character	None	Monitor shows message "Something wrong about command system"
,	Separate between first and second argument of scanf function	[Error] invalid operands to binary &	None	Monitor shows message "Something wrong about command system"
&	Refer to memory address of variable	Not show an error but the program shows message "A problem caused the program to stop working correctly"	None	Staff says "Can't put the number"
Price1	Variable name which use for store the input	[Error] expected expression before ')' token	Monitor shows message "Price is 5.50"	Staff says "The price has problem"
)	End of scanf function	[Error] expected ')' before ';' token	None	Monitor shows message "Something wrong about command system"
;	The statement terminator	[Error] expected ';' before next command	None	Monitor shows message "Something wrong about command system"

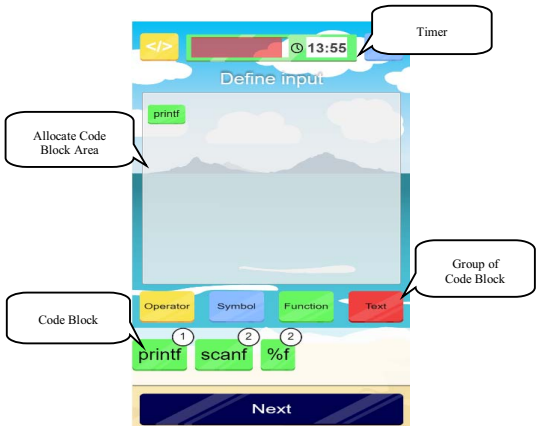

Fig. 1. The CPGame Layout

As shown in Fig. 2, it presents the example of defining input content. That is the case of learners' code block, which are incorrect, in case of learner forget to put the scanf code block in second line. The game activity will guide the learners via the game situation and show an error message. After that learner is asked to try allocating code blocks again for solve its error until the error is solved. In doing so, the learner could understand this content from error message and activity through game's scenario. On the other hands, Fig. 3 illustrates the case of learners' code blocks is correct, the game activity will show the events follow their code blocks which present the compiler working in the game situation.

After learners solve each content, they will get the reward and use it at the end of game. Furthermore, the game will show the time in which learner spend for solving the problem and show the ranking of three players who spend the lowest time.

IV. Research Design

A. Participants

This study is a pilot study and conducted on learners who learn in Fundamental of Computer Programming subject. Fifty freshmen were assigned to play the CPGame after learning the theory and before doing the lab assignment. During playing the game, they can learn, practice, and absorb the knowledge by themselves.

B. Research Tools

The pre-test was created by lecturers who expert and have experience in teaching a Computer Programming subject. This test aimed to measure the prior knowledge of the learners in basic of C programming language. The test consists of 20 items related to sequence structure concept. Each item was given 1 for the correct answer and 0 for the incorrect answer. The KR-20 was used to evaluate the reliability of the test, which confirms that the reliability value is 0.72. This result means the test has good internal consistency [18]. The learners were assigned to do pre-test before learning the theory, playing the game, and doing the lab assignment.

The motivation questionnaire was adopted from Glynn's [10] questionnaire relating to science learning motivation. It consists of 25 items, which is divided into five dimensions (i.e., intrinsic motivation (IM), career motivation (CM), grade motivation (GM), self-determination (STD), and self-efficacy (SEF)). This questionnaire is in five-point Linkert rating scales including 1-strongly disagree; 2-disagree; 3-neutral; 4-agree, and 5-strongly agree. This questionnaire aims to investigate learners' learning motivations after playing the CPGame. The Cronbach's alpha (α) value was used to evaluate the reliability of the questionnaire. The reliability value of the questionnaire was 0.94, showing good internal consistency of the questionnaire [19].

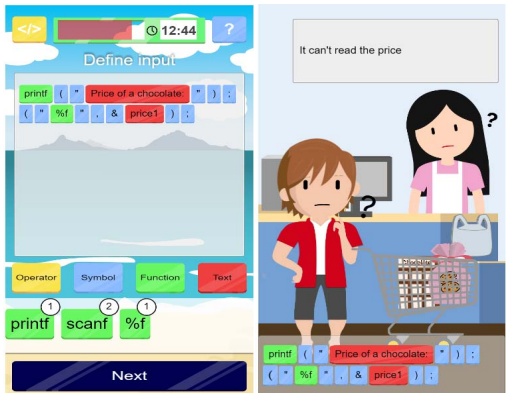

Fig. 2. Example of CPGame activity in case of incorrect allocate code block

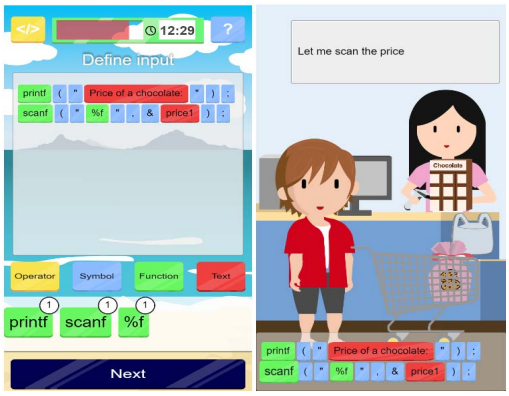

Fig. 3. Example of CPGame activity in case of correct allocate code block

C. Experimental Processes

The experiment was conducted during the content relating to the sequence structure of C programming language. During the experimental process, the researchers asked the leaners to take the pre-test (30 mins). The researchers then introduced the CPGame and its basic functions (10 mins). The learners were asked to spend time for playing the CPGame by themselves (50 mins). Finally, after finishing the game, they have to do the lab assignment (60 mins) followed by the motivation questionnaire (15 mins).

V. Research Results

This section presents experiment results, which consider the difference of learners' achieving levels. After learners took the pre-test, the Median Split was used to separating learners' achievement into two groups, in which high-achieving group (HG) consists of 30 learners who got the pre-test score greater

than or equal the median, and low-achieving group (LG) consist of 20 learners who got the pre-test score less than the median.

Considering the learning motivations of HG and LG in Table II, the groups of learning achievement are independent variables, while the motivation scores are dependent variables. Before conducting the one-way MANOVA test, the assumption of Box's M test of equality of covariance matrices was performed. It shows that the equality of covariance matrices was not violated with $F = 1.454$ and $p = 0.113$.

Therefore, one-way MANOVA test can be used to analyze the questionnaire ratings of five learning motivation dimensions. It presents that there is no a statistically significant interaction effect between HG and LG on learning motivations about the CPGame with $F_{(1, 48)} = 0.701$, $p = 0.626$ and Wilks' Lambda = 0.926.

TABLE II. DESCRIPTIVE RESULTS OF LEARNING MOTIVATIONS BETWEEN TWO GROUPS OF LEARNERS

Dimension	Group	N	Mean	SD
IM	HG	30	16.73	3.140
	LG	20	17.85	3.360
CM	HG	30	16.83	2.972
	LG	20	17.65	3.233
STD	HG	30	17.47	2.460
	LG	20	17.35	3.281
SEF	HG	30	17.37	2.251
	LG	20	17.40	3.068
GM	HG	30	16.83	2.995
	LG	20	17.45	3.634

VI. DISCUSSION AND CONCLUSION

This research analyzed the motivations to learn about basic C programming language on sequence structure of learners in higher education with different learning-achieving levels. By dividing learners into two groups (i.e., high- and low-achieving groups) for analyzing the relation of learners' learning-achieving levels and learning motivations after playing the developed game.

According to the results of the questionnaire, one-way MANOVA test presents that the CPGame affect to learners' motivations in both of high- and low-achieving groups with not differently. This is mean that the developed game could be a tool for supporting learners who are talent or impairment in learning C programming language. There are some reasons to support this finding. Because the CPGame provides enjoyable environment and interactive guideline for supporting low-achieving learners who are normally have negative attitudes, less interaction [20] and require more support or guidance [21]. Besides, the CPGame motivate learners to take responsibility for their own learning leading to intrinsic motivations for high-achieving learners who can learn the concept well [21] and have spontaneous learning [20] to learn in programming. Moreover, according to the results of this paper, it will be extending to consider about learners' performance because the motivation to learn will has positive effect on learners' learning abilities and construct knowledge basing on cognitive development [13].

VII. FUTURE WORK

For the next phase, the CPGame has been continue designed and developed to implement on mobile learning format. Because it has five characteristics of mobile devices i.e., portability, social interactivity, context sensitivity, connectivity and individuality). Besides, learners are not limited to learning inside classroom and can learn at any place and any time [22]. Furthermore, the success of this study leading to interpolate the learning performance evaluation in the further study. The results will be used for studying the relationships among learners' achievement levels, learners' motivations, and the learners' performance in learning C programming language by using the game-based learning environment via mobile-learning platform. The computational thinking skills will be a part of learning performance, which will be examined in the further study as well. Moreover, studying the level of learners' understanding in learning C programming will be analyzed by using the behavior analysis to evaluate the effect of the learning step-by-step process when learners are learning through the CPGame within the mobile-learning platform.

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