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An Innovative Module for Learning Computational Thinking Skills among Undergraduate Students

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Abstract
This paper outlines an innovative module for learning computational thinking skills through Mobile Application Development Module (M-CT). We have designed the module where students can not only learn and enhance their CT skills, but stay motivated throughout the learning process. The study involves a group of lecturers from Malaysian institutions of higher learning where their responses will be used in identifying the elements of computational thinking skills and type of native mobile applications that can be incorporated to develop the M-CT module. We set out to evaluate the effectiveness of a M-CT module in achievement, understanding and motivation among undergraduate students on computational thinking skills.
Keywords: Computational Thinking, Computational Thinking Skills, Mobile Application Development Module through Ct Skill (M-Ct)

Introduction

The Computational Thinking (CT) concept that was introduced by Seymour (1980) to develop a cognitive ability in problem solving through programming language (Lockwood & Mooney, 2017). Initially CT was part of basic concepts of computer science to solve problems, design system and understand human behaviours. The concept was further expanded by J.M Wing in 2006 who saw CT as a fundamental skill and envisioned computational thinking as an essential part of early education. In the expanded concept, (Wing, 2006) stated that humans can emulate the devices' thinking process and come up with solutions. The importance of computational thinking is later realized by numerous researchers after it has positively impacted humans' academic and personal lives (Denning, 2009) and how it plays a role in helping people to be more systematic and intelligent when analysing information (Lu & Fletcher, 2009; Sangakala, Ahmed, & Pahi, 2016).

In the field of education, computational thinking skills is used to enhance students' skills such as problem-solving, analytical, critical and creative abilities and innovative thinking as stated by the specific elements found in CT (Kules, 2016; Mohaghegh & Mccauley, 2016; National Academies, 2014; Perkovi, Settle, & Jones, 2010; Wing, 2006). In the age of digital literacy, students should be creative, possess critical thinking skills, excellent interpersonal and social relations(Nor et al., 2016). Skills play a role in highlighting the potential of an individual. A person with advanced skills will get more attention and respect compared to others (Ibharim, Yatim, & Masran, 2015; Matarid, Sobh, & Ahmed, 2018). Students with these skill set will have the ability to be successful in the society as they are able to solve problems and be contributor of ideas in the development of new world technologies (Kassan, Looi, & Tham, 2016). In the context of education in Malaysia, the Ministry of Education (MOE) has identified CT skills within the local contexts to provide Malaysians an analysis of things by providing systematic and logical solutions. It encourages a person to take a complex problem, analyse the causes and develop methods to make solutions. With the intention of transforming students in Malaysia into skilled and tech-savvy individuals, CT is integrated into the curriculum (Bernama, 2016) To meet this need, Malaysia became the first country in Asia to introduce CT skills in the curriculum as an effort to develop students with the skills required by employers (MDEC, 2017).

However, to ensure that CT is successfully implemented in the current education curriculum, it is necessary to incorporate various strategies, approaches and new teaching and learning methods that enables students to acquire and fully utilize CT skills. This view is supported by(Ibrahim, 2007; Mahamod & Noor, 2011) who both stated the need to emphasize strategies, approaches, teaching and learning methods that allows the newly introduced CT concept to achieve its objectives of producing students equipped with knowledge, skills, creativity in thinking and innovativeness to face the challenges of the present and future.

Despite the strengths of incorporating computational thinking in the curriculum; many researchers argue that the process of delivering the content has educational challenges (L'Heureux & Boisvert, 2012; Lee et al., 2011; Perkovi et al., 2010). The challenges are due to (1) the ineffective intervention used in the teaching and learning process (Gardeli & Spyros, 2017; Siiman et al., 2014), (2) a shortage of descriptions on the integration of CT elements in previous studies (Atmatzidou & Demetriadis, 2016; Kazimoglu, Kiernan, Bacon, & Mackinnon, 2012b; Lye & Koh, 2014)and (3) limited scope of activities conducted in the process of teaching and learning (Wang, Liu, Gu, Hu, & Wen, 2015). As a result of these three issues, the motivation to implement CT skills is still low among students, consequently affecting their achievement (Page & Gamboa, 2013; Romero, Lepage, & Lille, 2017; Weintrop et al., 2016). Motivation is a factor that can influence the development and learning of CT as it is a requirement in the learning process(Nikou & Economides, 2014; Palmer, 2005) . They should be exceptionally motivated for the acquisition of knowledge and generation of ideas to be more efficient(Ryan & Deci, 2000).

A preliminary study carried out in a Malaysian institution found that the results for computational thinking were less satisfactory when it is taught in traditional approaches. This is in line with findings by overseas researchers who reported that conventionally taught students find it difficult to understand the use of CT skills even at the basic level and before entering higher education(Lye & Koh, 2014).

A variety of designs is essential in the teaching of CT as the suitable design will facilitate in tapping CT's potential to broaden the way students think. Prior to the development of the module, it is noted that there are several native mobile applications that could be developed further. The advancement will go beyond games and robotic activities as the students will have the opportunity to learn and develop new applications via CT skills in App Inventor. This approach is backed by (Papert, 1991)who suggested that learning is most effective when students experience and discover new things for themselves.

The focus of this study is not only on the module's development but also on how effective the module is with regards to understanding and achievement including student motivation. This paper will elaborate further on the relevance of evaluating the effectiveness of these three elements as this study shows the role of the computational thinking skills module in producing students who master these skills well.

The Mobile Application Development Module through CT skill (M-CT) is module that allows students, particularly undergraduates, to assimilate CT skills in mobile application development. The aim of M-CT is to benefit students, bridge the achievement gap, and enhance students' understanding and motivation.

Conceptual Framework

The conceptual framework used to develop and evaluate a mobile application module to enhance computational thinking skills among undergraduate students is the integration two models which are the MADLC model and 5E model. The integration of the two models allows the identification of suitable activities for undergraduate students during the teaching and learning process in computational thinking and identify the appropriate elements of CT skills used in learning process.

Related Work and Discussions

In today's world, the computer provides numerous benefits and eases lives. (Curzon, Dorling, Ng, Selby, & Woollard, 2014) described CT as a mind-based activity that allows humans to systematically solve problems and understand the situation in detail through abstraction, decomposition, algorithmic design, generalisation, and evaluation in the production of an automation. Additionally, CT has a close relationship between computers and humans to solve a problem (Henderson, Cortina, & Wing, 2007). Wing, 2006 reported that CT concept is significant as it encourages an individual to think like a computer scientist. Originally, CT is a concept and methodology of basic computer science where it is described as a process of analysing problems similar to how a computer processes information in search of a solution (Aho, 2012; Yadav, Hong, & Stephenson, 2016). The term CT is also supported by (Mannila et al., 2014) as it covers a set of concepts and thought processes that help to solve complications in numerous fields. Several researches later discovered that CT can be integrated in other subjects to solve problems(Wing, 2006; Zhong, Wang, Chen, & Li, 2015). In addition, the knowledge on CT will help students to deal with daily challenges they face in their lives.

Computational thinking involves skills that often include decomposition of a problem, pattern recognition, abstraction, and formulating algorithms to solve issues. (Kules, 2016) stated that computational thinking is critical thinking that can be created through elements of abstraction, decomposition, algorithmic design, generalisation and evaluation and iteration. Abstraction is a stage of listing all ideas and during the process, illogical ideas are rejected. Decomposition is where problems are broken down into smaller parts and algorithm design is a structure to resolve problems. Generalization is the process of taking one or a few facts and making a broader, more universal statement. Evaluation assesses an existing item and iteration repeats the similar process from the beginning for another issue. (Philips & Bond, 2007) stated that CT emphasized more on knowledge building, presentation skills and facilitating innovation through three elements: Abstraction, Automation and Analysis as shown in Figure 2.1:

Skills	→ Element of CT
Building knowledge	→ Abstraction
Presentation skills	→ Automation
Innovation	→ Analysis

Figure 2.1 Skills

(Bers, Flannery, Kazakoff, & Sullivan, 2014) developed a curriculum using CT elements to develop CT skills, problem representation, ability to generate systematic solutions and giving multiple solutions at any level of problem-solving. In a Form Four Computer Science subject, four elements namely decomposition, pattern recognition, abstraction and algorithm are integrated to help students to understand problems and develop a rational solution when facing complex problems(Geck, Hooi, Mohamad, & Ismail, 2016). (Kazimoglu, Kiernan, Bacon, & Mackinnon, 2012a) reported that through game development, they have integrated five elements of CT, problem solving, building algorithms, debugging, simulation and socializing to build CT skills such as critical thinking and problem-solving skills. Besides, the combination of CT is possible through decomposition, logical use, algorithms and application of innovation to resolve a problem through separation method as it combines logic, arithmetic, efficiency to create quality of innovative thinking(Black et al., 2013).

CT has been integrated into the teaching of Science, Technology, Engineering and Mathematics (STEM) in some countries, however, Malaysia became the first country in Asia to integrate CT into the secondary school curriculum (MDEC, 2017). In this curriculum, four elements are integrated as shown in Figure 2.2 below:

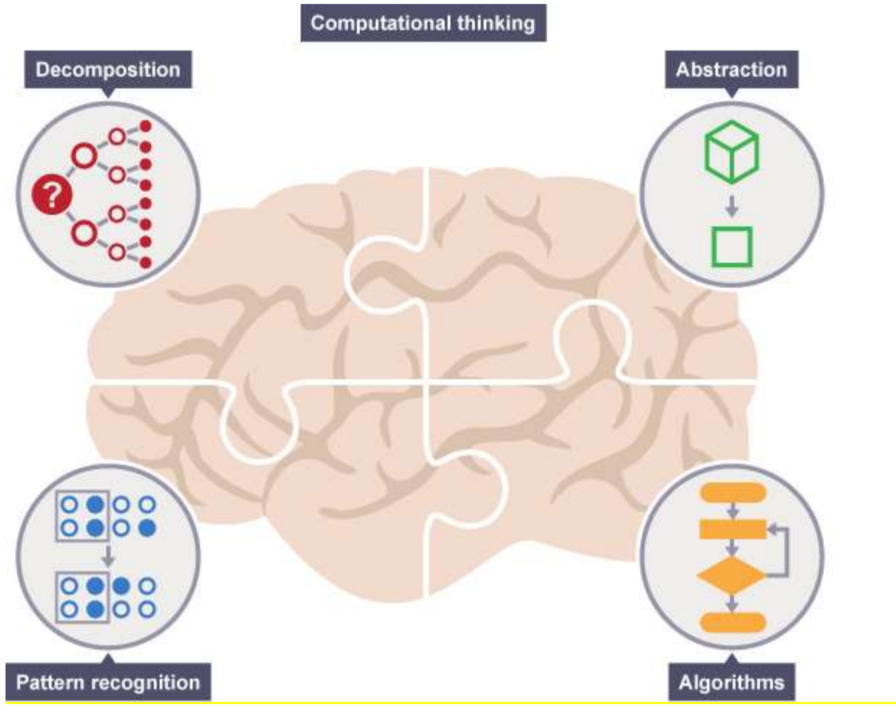

Figure 2.2 Computational Thinking
Source: (Kassan et al., 2016)

Problem solving models can be in the form of formulas, techniques, rules or steps. The four elements used to solve the problem in this module is decomposition, pattern recognition, abstraction and algorithms (Kassan et al., 2016). Decomposition defines an important aspect of a problem by unravelling a big problem with small parts that are easier to solve. The smaller parts can be examined and solved or designed individually as they are simpler to work on hence allowing the problem to be solved easily. Pattern Recognition indicates similarities or differences of some problems. Research on similarities and patterns in these smaller issues can help solve complex problems effectively. Abstraction is a technique used to define important features in an issue. This technique leaves the less important aspects of the patterns that are familiar and focus on important aspects that can help in resolving problems.

Study Design

Design and Development Research (DDR) is a systematic study to build instructional and non-instructional products, tools, new models or modifications that drive development (Richey, Klein, & Nelson, 2004).It is a category of pragmatic research guided by the theory, practice-oriented, participant-centred, and collaborative, with the aims of testing and verifying the theory in practice. In addition, it is one way to generate procedures, techniques and new equipment based on the analysis methodology of a case.

In this study, DDR type 1 is used in the M-CT module developed as a teaching and learning product, designed specifically for the context of higher education. Type 1, mixes quantitative and qualitative approaches through various methods in each phase according to the needs and suitability of the study which, are based on the characteristics of the student's approach to the research. The rationale for the merger of these two methods, is to provide a more accurate and wider data set for the researcher to observe, thus enabling a comprehensive overview of the work (Creswell, 2015). Furthermore, the combined method gives the researcher the use of a variety of tools in the collection of data.

Design and development research have three phases. For the evaluation phase, a quasi-experimental design (non-equivalent control) was used as the Registrar of Institution A did not encourage re-arrangement of the existing classes but allowed the flexibility to choose any semesters to conduct the study. This is because the students are assigned according to their respective sections and any changes would affect the lecturers and students' timetables. Consequently, existing classes are used via random selection, dividing the semester into control, treatment and pilot studies. The process of quasi-experimental design used in this study is shown in Table 3.1.

Table 3.1 The design of non-equivalent control group

Group	Pre-Test	Intervention	Post-Test
Control	O_1	Conventional	O_2
Treatment	O_1	M-CT module	O_2

The respondents in treatment and control groups will sit for pre-test (O_1) before beginning a teaching and learning session on computational thinking topics. Subsequently, respondents in the control group learn computational thinking skills using conventional approaches and the learning materials are provided. The respondents in the treatment group are taught the same topics, but with integrated computational thinking skills in a mobile application development module. The variables involved in this study are that the study groups used different methods of intervention; the treatment group used the M-CT module and the control group used the conventional method. At the end of the teaching and learning session, a post-test (O_2) will be conducted for both groups.

Validity

Threats to research validity can be divided into two categories, namely the threats to internal validity and threats to external validity. Internal and external validity have their respective components to reduce threats and increase validity. Internal validity has eight factors consisting of history, maturation, testing, instrumentation, statistical regression, selection bias, mortality and interaction of selection-maturation, while external validity, has three factors consisting of interaction of selection and treatment, environmental interaction and treatment, and historical interaction and treatment.

Respondents

Purposive sampling was used in selecting respondents which involved students from an institute that provides both IPTA and IPTS courses. Institute A offers similar courses which are Bachelor of Business Administration (Hons) in collaboration with three different institutions. The location of study for all three institutions is in Seremban 2, Negeri Sembilan. The institution is also selected as it is well equipped with computer laboratory, internet connection and projector in the lecture room. Additionally, it also meets the criteria listed the internal and external validity to reduce threats during the course of this study.

Instrument of Research

Two instruments are used in the study to gauge the effectiveness of the mobile application development module, to enhance the level of achievement, understanding and motivation on computational thinking skills. The researcher used pre-test and post-test to assess the effectiveness of achievement on computational thinking skills, a questionnaire to evaluate the effectiveness of understanding through three-dimensional CT, and Motivated Strategies for Learning Questionnaire (MSLQ) to evaluate the motivation among students. All instruments are used in both groups (treatment and control). Pilot study is carried out to obtain information on how to effectively administer the experimental instruments and establish the time required to answer each instrument. The pilot study also determines the contents are valid in pre-test, post-test and questionnaire by involving students who have similar backgrounds to the actual study respondents.

Pre-Test and Post-Test

Pre-Test and Post-Test are designed to identify the level of achievement on CT skills among students. Two sets of equivalent exams were set up to be used in pre-test and post-test. The pre-test and post-test consist of six elements which are remember, understand, apply, analyse, evaluate and create. The Post-test is given after the intervention to evaluate the achievement of CT skills between the treatment group (M-CT module) and the control group (conventional).

Questionnaire of CT Skills

The questionnaire of CT skills is divided into three parts, namely the determination of the semester before the study begins, Three-Dimensional of CT and Motivated Strategies for Learning Questionnaire (MSLQ) to determine whether students' motivation and understanding of computational thinking skills are enhanced or not through M-CT module.

In the first part, determination of the semester questionnaire determines which group of semesters has high interest in learning CT skills and has no experience in mobile application development. The purpose of using this questionnaire is to determine whether the standardised control and treatment groups are the same and threat is reduced in terms of internal validity and external validity.

In the second part, the MSLQ will be distributed to get the opinions and views from the respondents (treatment and control) towards motivation on CT skills. This questionnaire consists of five domains of motivations which are Intrinsic Goal, Extrinsic Goal, Task Value, Control of Learning Beliefs and Self-Efficacy. This MSLQ questionnaire, which as mainly constructed by (Pintrich, Smith, Garcia, & McKeachie, 1991), aims in evaluating the level of motivation and learning strategies among students.

In the third part, the questionnaire is designed to evaluate students' understanding of computational thinking skills based on the tasks assigned in their respective intervention, consisting of a three-dimensional approach that consists of concepts, practices and perspectives. The concept questions are designed through the CT skills elements used in interventions, practicing based on students engaged with the concepts and perspective meaning that involves students to develop their understanding of CT.

M-CT Module Review Questionnaire

The M-CT Module Review questionnaire is divided into three sections: Part A is self-information, Part B evaluates module items such as text, content, objectives, pedagogical approaches and learning theories. Part C has the experts' comments and views on the advantages and disadvantages of the module. Additionally, the lecturers teaching in the pilot studies were also involved in evaluating the module.

Procedures of Data Analysis

The data will be numbered by lines after the completion of the interview. This facilitates the process of identifying specific lines that provide the necessary information. This is known as the process of organizing data by establishing codes, themes and data categories. To facilitate the process of analysing interview data, an interview transcript was entered into the Atlas application. Atlas is an app that helps researchers analyse their qualitative data. The theme has been released based on the data obtained and are examined to see if there is a relationship or a relationship with each other. This stage leads to the development of the module in the study.

Quantitative data collected from the instruments (test and questionnaire) are encoded and inserted into the computer. The data was processed and analysed using the SPSS Version 21. The quantitative data obtained was analysed using two types of statistics which are descriptive and inferential. All data is processed, compiled and formulated in the form of tables or graphs to facilitate the analytics report.

The data were analysed descriptively using percentage, frequency, mean and standard deviation. This descriptive analysis is used to describe the overall profile of respondents, the level of achievement in pre-test and post-test, the effectiveness of the mobile applications through CT elements, and the level of motivation for both groups after interventions. The inferential statistical analysis used in this study includes the T-test and ANOVA.

Procedure of Research (Por)

POR describes the procedures performed throughout the study process. It begins with a requirement analysis until all the data or information obtained is analysed. The discussion of the study procedure is divided into three phases namely the need analysis phase, design and development phase and lastly the evaluation phase.

Need Analysis Phase

Needs analysis is an important component of the development process as it identifies the cause of the gap in the development process. It also aims in identifying the root cause of a gap in the performance of a course and determine which gap can be solved with the interventions carried out (Akbulut, 2007; Kemp, Ross, & Morrison, 1998). To achieve the objectives, reference to any relevant past studies and obtain information through lecturers and experts using the Grounded Theory qualitative method is required.

Design and Development Phase

The development of the CT Module through mobile application is the main objective of the study. The steps to ensure that this module, which is based on Kemp's Model, is well developed as the module is used to enhance computational thinking skills(Kemp et al., 1998; Lay, 2017).

The module has been refined and improved as it has been sent for review to three experts for content validity. Additionally, the module was also proofread by two English language editors to ensure the validity of the language used. Subsequently, pilot studies were conducted to ensure that the modules were developed systematically and impact the students positively

Evaluation Phase

After the completion of the M-CT module and instruments, the data obtained will be used in evaluating the effectiveness of the level of achievement, understanding and motivation. Prior to the execution of the study, the lecturers involved were briefed on this assessment phase as the respondents are made up of Institute A students. Pre-test scores, post-test and data obtained from the questionnaires were coded in SPSS software for analysis based on the research questions. The lecturers are also allowed to see the variances that exist in the approach and pedagogy used in the module. The respondents were also well informed on how the two methods aids in developing CT skills and its enhancement via mobile application.

Conclusion

This paper illustrated an innovative approach to enhance CT skills among students through a mobile application development module. The effort to create a design-based learning approach module that can meet the needs to master CT skills will benefit students, faculties, lecturers and higher institutions. This module can be used as a well-planned learning tool, enabling students to implement it systematically by describing the steps and requirements to follow. The mobile application development can also provide a learning environment that is fun, exciting, and comfortable to the current digital generation. With the data obtained, we will be able to validate our research as the findings will enable us to address all the issues raised by the students to improve the module.

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