Incorporating the Elements of Computational Thinking into the Mobile Application Development Life Cycle (MADLC) Model

Letchumanan Shanmugam, Siti Fatimah Yassin, Fariza Khalid

Abstract*: Computational Thinking (CT) is a term of great interest which elicits a good response from researchers. Most researchers have become aware and pay much attention to CT because most industries have begun to focus on computational thinking skills, in addition to future work skills. One of the critical skills required among graduates is CT. Additionally, smartphones and mobile devices have become ubiquitous and more people now access the web via mobile devices than from personal computers. As the number of devices expands dramatically, users are becoming accustomed to having both web and computing access via small, mobile devices and phones. Development, as well as mobile device use, has become increasingly popular amongst students. In mobile application development, one of the models that can be used is the Mobile Application Development Life Cycle (MADLC). Therefore, in this paper we integrate the elements of CT into the MADLC model hoping to provide broad benefits not only in its development but in the use of CT skills. For the appropriate CT element determination that integrates into the MADLC model, we conducted interviews, observations and document analysis. All of the experts we interviewed regarding computational thinking stated that elements of computational thinking are able to be integrated into mobile application module development. From the interviews of all experts, we identified the appropriate CT elements that could be integrated into the MADLC model, namely abstraction, algorithm, decomposition, pattern recognition and evaluation.

Index Terms*: Computational Thinking, MADLC Model, Mobile Application Development.

I. INTRODUCTION

The educated young generation of today is potentially an important source for the improvement of the country's economy. According to [1], the strength of a country lies in the level of knowledge and skills of its population. [2], [3] said that in order to achieve a scientific, progressive and innovative society, it requires citizens with critical thinking and problem-solving skills, especially from highly educated people. Besides that, in the digital age of the 21st century, students require technological literacy skills, including being creative, have critical thinking skills, and excellent interpersonal and social relationship abilities [4]. Hence, various efforts have been undertaken to enhance the skills available in a student to transform the society into a skilled and tech-savvy society. One of the efforts is to integrate Computational Thinking (CT) into the curriculum [5], [6].

CT is an effort to cultivate and improve problem-solving skills towards producing critical and creative minded students. Students with this skill can solve problems and contribute ideas in the development of new world technologies [7]. In addition, CT provides an opportunity for individuals to enhance their knowledge, skills, standards of living and become successful people in society. Furthermore, the successful implementation of CT and the transformation of education requires strategies, approaches and new methods of teaching and learning that enables students to acquire and fully utilize CT skills[8].In addition, we integrated the mobile application development model (MADLC) where students can design applications by integrating computational thinking. This could be said to be a design-based approach for learning CT skills among students. Mobile Application Development is an exciting subject among students. Besides that, demand for mobile applications in all industry sectors is growing and it also directly helps increase the country's GDP [9]. Other than that, most of the plans were introduced in countries either as Internet of Things (IoT), 21st century skills or the Industrial Revolutions. All of these strategies focus and emphasise digital technology, hence the reason why we used the mobile application development model in this paper.

A. *Research Objectives*

The focus of this paper is to identify the elements of computational thinking skills that can be incorporated into the mobile application development model (MADLC).

II. LITERATURE REVIEW

A. *Computational Thinking*

The Computational Thinking (CT) concept that was introduced by Seymour (1980) was to develop a cognitive ability in problem solving through programming language [10], [11]. In 2006, Wing expanded the concept of CT and stated that it was a fundamental skill and almost suitable for everyone[12]. In the beginning, [12] involved CT in the basic concepts of computer science in problem solving, system design and understanding of human behaviours. Besides, Wing mentioned that CT is not a computer or machine to create a solution, but we can think of it as the processes inside the devices provide solutions. This process was generated by a computer scientist, who

Revised Manuscript Received on June 11, 2019.

Letchumanan Shanmugam, Faculty of Education, The National University of Malaysia, Selangor, Malaysia.
Siti Fatimah Yassin, Faculty of Education, The National University of Malaysia, Selangor, Malaysia.
Fariza Khalid, Faculty of Education, The National University of Malaysia, Selangor, Malaysia.

stated that almost everyone can think like a computer scientist and apply CT concepts in any situation to easily solve a problem[12]. Most researchers agreed and accepted her idea and integrated this concept into their respective studies. Computational thinking is a problem-solving method which can see a solution in various ways [13], [14].The importance of computational thinking is realized by various parties once it has had a positive impact on the academic as well as the personal life of a human being [15]. CT helps people to be more systematic and intelligent when analysing information [16]. CT is the concept and methodology of basic computer science that can not only be integrated into computer subjects but can also be integrated into other subjects to solve a problem [12], [17]. CT is the process of analysing problems, like a computer process to facilitate a solution [12], [18]. This is also supported by [19], [20] who said that CT is a term that covers a set of concepts and thought processes that help to solve problems in various fields. [21] stated that the strategy of cognitive thinking is one of the features in Computational Thinking, because a computer scientist thinks to create solutions. [22] also outlined that CT is a set of skills to make people know how to think rather than how to develop a programme. This is because most people's perception is to have at least some basic knowledge about programming language if they want to learn CT. This is an incorrect perception. Actually, CT is integrated into programming or applications to facilitate understanding of the CT concept. According to [23] most past studies use a different programming language to introduce and facilitate understanding of the CT concept. This is supported by [24] who said that beginners can easily learn and understand the CT concepts when integrating the CT elements into project-based learning. Besides, [3] states that computational thinking is critical thinking that illustrates how to solve problems, make decisions and also know its application in careers. CT can encourage students to do something better in a subject through critical thinking. In addition, [25] said students are able to think critically according to their ability, including identifying the constraints in those ideas through CT. In today's world, the computer provides a lot of benefits and makes life easier for humans[12] said that the CT concept encourages a human being to think like a computer scientist. Additionally, CT has a close relationship between computers and humans in problem solving[26]. Any solution using a computational thinking approach will go through the elements of how a computer processes decomposition, abstraction, pattern recognition, generalization, evaluation, iteration, automation, communication, computation, coordination, design, evaluation, recollection, problem-solving, innovation and algorithm. Based on [27] CT is 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 automation.[28] integrates five elements of CT, problem solving, building algorithms, debugging, simulation and socializing to build CT skills such as critical thinking and problem-solving skills through game development. Computational thinking and problem-solving strategies enable humans to generate problem solving methods such as computers that generate solutions to a problem. Besides, CT can be integrated into decomposition, logical use, algorithms and also to apply innovation for a problem to be resolved through the separation method including the solution. It is also a combination of logic, arithmetic, efficiency, and the creation of quality of innovative thinking [29]. Computational thinking involves skills that often include decomposition of a problem, pattern recognition, abstraction, and formulating algorithms to solve it. This method can also be implemented in the same situation in different places [30].People with CT skills can help improve the country's economy and reduce unemployment rates through the existence of skilled individuals. CT skills emphasize skills and capabilities for students, not on the content of STEM subjects [31]. CT skills emphasize problem solving skills to provide students with more creativity and critical thinking as well as enhance the students' existing capabilities and abilities. [32] has identified CT skills to the local context in order to meet the aspirations of developing first class human capital in preparation for the challenges of the 21st century. [33] state that 21st century skills can be developed through the elements of CT. 21st century skills emphasize the creation of capable students in applying technology through digital literacy, creative and critical students in thought who possess excellent interpersonal and social skills [4]. In the unpredictable global economic environment, it is better to prepare for the development of human capital that has competence in skills, especially the skills required by employers. 21ST century skills aim to enhance productivity that can only be realized with technology-literate workforce groups and critical thinking skills to compete with the global economy of the country [34]. Education is a strong foundation which is the core of the labour force in producing a healthy, skilled and smart workforce to allow the country to compete successfully in world markets. The strategy will be implemented to make the school a platform to nurture creative thinking and learning skills that are essential to future manpower needs [35].According to [36], education should not only address the repetition of what has been done by past or present generations, it is necessary to grow individuals through innovative skills. Education allows the individual to adapt to uncertain global changes and situations. Therefore, the institution should provide a skilled human resource in line with the needs of the 21st century through CT skills. As defined by [37] 21st century literacy is a set of capabilities and skills that overlap between digital, visual and aural literacy. This includes the ability to recognize and use power to understand the power of image and voice, manipulate and transform digital media, disseminate information widely and more easily adapt it to new forms. Hence, the capabilities and skills of using technology and achieving information and interpreting them in understandable and global forms are indispensable in the 21st century. Therefore, the implementation of CT skills, especially in the curriculum of higher education, will speed up to the process of achieving the goals of the 21st century.

B. *Mobile Application Development*

When Mobile technology has today become a visible part of students' lifestyles

[38]. The development and advancement of mobile technology in education has grown rapidly. The development of mobile technology in the world has had a huge impact on the life of a student. This technology is made up of technological tools that are small and can be carried anywhere [39]. The use of smartphones is growing in the community. In Malaysia, 87.9% of the population use smartphones for accessing the Internet and social media such as Facebook, WeChat, WhatsApp, Twitter, and so on [40]. Additionally, the most popular operating systems used in Malaysia are Android and iOS. Android OS was developed by Andy Rubin, Rich Miner, Nick Sears and Chris White in 2003 in California. In 2005, Google took over from them to expand Android usage [41]. iOS was developed by Apple in 2007 and it only supports Apple branded devices. Both operating systems are unique in accordance with the applications installed by the user. In addition, the operating system is very important for a smartphone to perfectly function. Mobile applications consist of three types, namely native applications, mobile-web applications and hybrid applications, as shown in Table 1 below:

Table 1:Feature of native, mobile-web and hybrid applications

Features	Hybrid Application	Native Application	Web Apps
Development Language	HTML 5, Java Script and SDK Tool	Native only	HTML 5
Performance	Good	Very Fast	Dependent on Web Browser
Code Portability	High	None	High
User Interface	Moderate	High	Moderate

C. *Mobile Application Development Model*

In the development of mobile applications there are various models, and one of the models is the MADLC model. This model is very suitable for use because it is more accurate, systematic and has easily understandable phases for application development[42], [43]. In this model there are seven phases, each of which are described in Table 2.

Table 2: Process of MADLC according stages
Source: [42], [43]

Phases	Process
Identification	Identification means generating new ideas to find a solution through a mobile application. The ideas need to be analysed in detail and identify the scope of application before the next phase.
Design	Developers should decide whether a trial version or premium version of the software is to be used to develop the mobile application. Then, create the storyboard for the user interface design based on the software decided. In the storyboard, the flow of the application can easily be described.
Development	In this stage, the interface design will be integrated with the programming language. The development process is divided into two parts: programming for functional and user interface requirements. Functional programming means the scope and purpose of the application and programming for the user interface requirement means the process of application with multimedia requirements such as buttons, hyperlinks and images.
Prototyping	In this stage, the application will be tested by experts to check whether it has met the requirements or not before being forwarded to users. If they are not met, the developers should do more tests on their application until the requirements are met and there are zero errors in the programming.
Testing	Testing is one of the most important stages in this model because the most rigorous tests use targeted users. Their testing is through real devices.
Deployment	Deployment is the final phase of the development process. After the testing is completed and the final feedback is obtained, the application is ready for deployment. The application is uploaded to the appropriate application store for user consumption.
Maintenance	Maintenance is the last stage of this model and is also a continuous process to make improvements according to user output.

III. METHODOLOGY

We conducted semi-structured interviews, observations and document analysis to identify the elements of CT that are suitable for incorporating into the MADLC model. For this, we interviewed experts who have extensive experience in computational thinking and also those who are well versed in mobile application development. Experts involved in this process are lecturers, trainers, corporate members and mobile application developers. For mobile application developers, we used semi-structured interview protocol questions which were different, but the scope of the questions was similar to those used for lecturers, trainers and corporate members. This is because mobile application developers are more experienced in companies compared to lecturers, trainers, and corporate members who have experience in the education field. According to [44] a variety of questionnaires can be used for different fields of experts' experiences for answering the specific scope of research questions. This causes the investigators to use different protocol questions.

The interview protocol questions are divided into two parts, namely demographic information and questions that can answer research questions. In addition, we also conducted observation and document analysis to strengthen data outcomes from interviews.

IV. FINDINGS OF INCORPORATED ELEMENTS OF CT INTO THE MADLC MODEL

A. *Demographic Information*

For demographic information, all respondents are selected based on the criteria of experts who carry out teaching in computational thinking skills or who have extensive experience in the development of mobile applications, or both. In addition, the respondents also have academic qualifications at the undergraduate/postgraduate level and have experience in the field of education or industry for a minimum of five years. Expert selection is aimed at obtaining useful information to identify elements of computational thinking. Table 3 shows the demographic information of the respondents involved in this study.

Table 3:Demographic information

Respondent's Code	Institute/ Working Place	Level of Education	Teaching/ Working experience
R1FM	PU1	PHD	8 years
R2FM	PU1	PHD	20 years
R3FM	PU2	PHD	15 years
R4FM	PU3	MASTER	10 years
R5FM	PU4	MASTER	13 years
R6FM	PU5	PHD	11 years
R7FM	PU6	DEGREE	11 years
R8FM	PU7	DEGREE	8 years

After the interview was recorded, we converted it into a transcript. The data was categorized into a theme based on semi-structured questions and then analysed to produce themes to answer the questions of study (1) and (2).

Research Question 1 (RQ1):

A description of research question 1 is as follows:

a. What are the elements of computational thinking skills that can be integrated into the mobile application development phases (MADLC model)?

All eight experts in the field of computational thinking said that elements of computational thinking can be integrated into the development of mobile application module. From the discussions with experts in the field of mobile application (R7FM and R8FM), we have identified that they are indirectly integrated into the CT elements of mobile application development. From the interviews of all experts, we identified the appropriate CT elements that could be integrated into the MADLC model. Elements that have been identified are categorized into the following themes and results:

i. Abstraction

R1FM LINE 60: "….is a key element and can be integrated into the module. Hmmmmm, why abstraction is a fundamental element in CT because it focuses on the important and ignores unrelated things. So, students can clarify which is important for the development process…."

R2FM LINE 57: "…plays an important role. For example, between user and developer. Most of these users are just good at using the system but they are not bothered to do the coding that is operating inside of the system. However, developers focus on both. From here, we know both of them applied abstraction but in different angles…."

R3FM LINE 70: "…can be said as described in a theses or articles. More focused on the main thing. But, abstraction cannot simply be integrated into mobile application development, you should select one model development in mobile application. For example, SDLC model, waterfall model, MADLC model and so on ... Based on the model selected, you should have integrated abstraction into suitable phase…."

R7FM LINE 66: "… to understand the requirements of the user – the research and analysis stage..."

R8FM LINE 56: "…features are important in mobile application, purposes and objectives…."

ii. Algorithm

R1FM LINE 63: "…can also be integrated in your module. Make sure this algorithm is described primarily pseudocode and symbols of flowchart. This is because students are still confused how to use pseudocode and flowchart even in the final semester. I hope this module will help students and make sure you explain clearly about the activity that represents algorithm…."

R5FM LINE 64: "… which helps and shows step-by-step of a solution. In your module if you integrate algorithm it really is helpful for students to learn pseudocode and flowchart…."

R6FM LINE 65: "… algorithm is a set of rules for solving a problem. This rule is orderly, clear and effective in solving the problem…."

R7FM LINE 75: "… always a conceptual design of the application we are about to make. Without this concept the developer can get lost in their mental understanding and their mental picture of the application. It is always best to sketch it on a paper and then build upon it. …."

R8FM LINE 66: "…should draw the flowcharts and algorithm for mobile application…."

iii. Decomposition

R2FM LINE 61: "…elements can also be input in the module. Because students can break them into small parts of design. From there, students can create codes for each design needed codes…."

R3FM LINE 75: "…can be divided into code and design. Modules you want to develop are more to develop process, so you should focus on decomposition…."

R7FM LINE 112: "…the code for navigation bar can be used again and again because many applications require a navigation bar …."

R8FM LINE 61: "…completing from bottom to top…."

iv. Pattern Recognition

R3FM LINE 78: "…If you apply visual programming language platform, you should integrate pattern recognition technique. Pattern recognition can easily match the code based on colour…."

R5FM LINE 64: "…is more complex when writing codes are used to generate design. But, in your module, students will use visual programming language so you can use

pattern recognition elements. In addition, pattern recognition is also one of the fundamental elements in CT…."
R7FM LINE 104: "…missing out on a step means sabotaging the whole development process.…."
R8FM LINE 79: "…same steps to design the mobile applications…."

V. EVALUATION

R4FM LINE 65: "…assesses the product developed by the student. Process can be divided into questionnaires or interviews. From this process, students can find out where to make improvements in the product. Do not forget to include basic components as in the syllabus as well…."
R5FM LINE 72: "…I think, it is already mentioned the important component you should apply in your module. Actually, you should apply the basic components stated by Wing in your module. It is important how you are going to integrate it in your module…."
R7FM LINE 91: "…we never really hand out the first prototype to our clients. Usually, it's the third or fourth version. This iterative nature of development helps us to deliver robust applications.…."
R8FM LINE 72: "…present to project's head and clients…."
In summary, the analysis of the interviews of eight experts said that the MADLC model can be integrated with the elements of CT, namely abstraction, algorithm, decomposition, pattern recognition and evaluation. Table 5 summarizes the results of the interviews of eight experts in the needs analysis phase for RQ1.

Table 5:Summary of expert results for the integration elements of CT into M-CT module

Theme	R1FM	R2FM	R3FM	R4FM	R5FM	R6FM	R7FM	R8FM	Frequency
Abstraction	/	/	/	/	/		/	/	7
Algorithm	/			/	/	/	/	/	6
Decomposition		/	/	/	/		/	/	6
Pattern Recognition			/	/	/		/	/	5
Evaluation				/	/		/	/	4

In addition, in order to strengthen interview data, we conducted document analysis on the syllabus of computational thinking that was used by one of the higher education institutions. In the syllabus there are four topics, namely abstraction, algorithm, decomposition, pattern recognition that should be studied by students to improve problem solving skills and to understand the basic CT concept in depth. The summaries of the syllabus are shown in Table 6.

Table 6: Summary of syllabus computational thinking

	Topics	Learning Outcomes
1.0	Introduction to Computational Thinking	Computational thinking requires skills for defining a problem and formulating a proper question to answer. When one is faced with a real-world problem the first step towards an efficient solution is to define a problem for automation. It might sound as though it is an easily learned ability, but it requires a deeper understanding of abstraction, algorithm, decomposition and pattern recognition and the more effective solving of problems.
2.0	Definition Computational Thinking	
3.0	Concepts of Computational Thinking	
4.0	Element of Computational Thinking	
5.0	Algorithms	
6.0	Define	
7.0	Pseudocode	
8.0	Flow Chart	
9.0	Decomposition	
10.0	Decomposing a Problem	
11.0	Pattern Recognition	
12.0	Matching same pattern	

It is also similar to that said by expert R4FM about element of CT as follows:
R4FM LINE 60: "…according to the syllabus, there are 4 components that students learn: abstraction, decomposition, algorithm and pattern recognition. You should apply all this in your module…."
In conclusion, we answered the questions of the study according to the results of the interviews and the document analysis, whereby the elements of computational thinking skills that can be integrated into the MADLC model are abstraction, algorithm, decomposition, pattern recognition and evaluation as shown in Fig. 1 below.

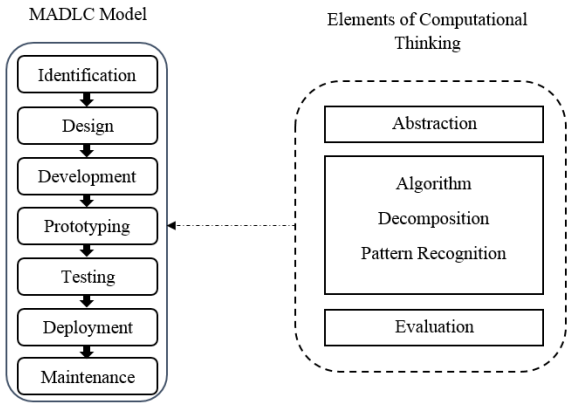


Fig. 1: Integration of MADLC model and elements of computational thinking

Research Question 2 (RQ2):
b. How can the elements of CT be integrated into the mobile application development phases (MADLC model)?
Experts said as follows:
R1FM Line 79: "…explains about the important things so it can only be applied to the first phase and algorithm normally we apply in designing phases. This is because the algorithm is more related to the development process. If you

design wrongly the algorithm will affect the development process. It is better you integrate it into design phase…."
R2FM Line 66: "…abstraction can be integrated into the first phase and decomposition into the design phase…."
R3FM Line 83: "…abstraction can be integrated in the first phase. Usually in the first phase we describe the importance of the product or objective. Abstraction is more appropriate in the first phase. For decomposition and pattern recognition can be integrated into the design phase…."
R4FM Line 77: "…first phase in MADLC model is the integrated abstraction and evaluation for testing and prototyping phases. The rest all integrate into design phase…."
R5FM Line 75: "…algorithm into identification phase and pattern recognition into design phase…."
R6FM Line 71: "…algorithms integrated into identification phases…."
To reinforce the interview data above, we conducted the observations at two companies (C1 and C2) where developers develop mobile applications. Based on observations, we found that mobile application developers integrate CT elements indirectly while developing mobile applications such as abstraction, decomposition, algorithm, pattern recognition and evaluation. In mobile application development, abstraction is used to discuss important issues and focus on important aspects that can help in solving problems, decomposition is used for breaks in the design and code, the algorithm is used to see the development process run smoothly in the first phase through the flowchart and evaluation is used in the last phase to look at whether the design has met the client's requirements. All of these processes integrate in a model of methodology to ensure that the project runs accurately and systematically.Fig. 2 shows the abstraction, algorithm, decomposition, pattern recognition and evaluation incorporated into appropriate phases in the MADLC model as specified by experts, including observation from two companies done by us.

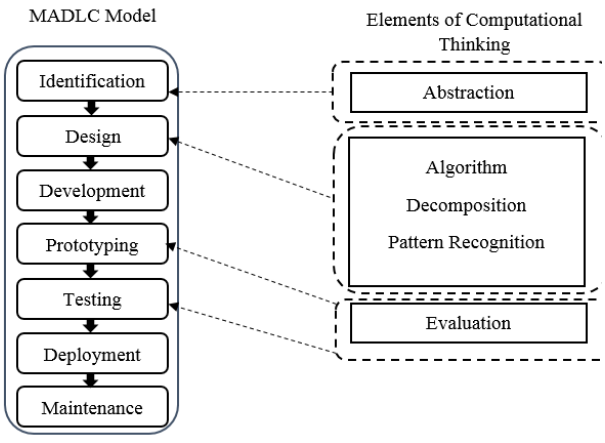


Fig. 2: Incorporated elements of computational thinking into appropriate phases in the MADLC model

Table 7: Incorporated elements of computational thinking into specific Mobile Application Development Life Cycle (MADLC) phases

MADLC model phase	Elements of computational thinking incorporated into MADLC model
Identification	**Abstraction** Focusing on key matters that are relevant.
Design	**Algorithm (Pseudocode, Flow chart)** Describes a process by using flowchart diagram or text-based pseudocode. Pseudocode describes algorithm steps using simple and compact sentences. **Decomposition** In order to break into small parts, horizontal hierarchy diagrams can be used. **Pattern Recognition** Pattern Recognition is a process of finding similarities in small parts when solving complex problems by using decomposition.
Prototyping	**Evaluations** In this stage, the application will be tested by experts to check whether it has met the requirements before being forwarded to users.
Testing	**Evaluations** Testing is one of the most important stages in this model. Thus, testing must be carried out rigorously with targeted users through real devices (Pilot-test)

For the understanding of the reader, we have attached an example of a mobile application development, that is the 'Hyperlink App' using the MADLC model that incorporates CT. This app was developed through App Inventor 2.

A. *Future Work*

The scope of activity in the teaching and learning process of CT needs to be wide. According to [45] to teach complex computational thinking skills through educational robotics activities is an effective strategy. Based on further research, [28] argued that if learning content was presented with a game, it was easy to develop students' understanding of how the CT concept works.[46] suggests that game design requires computational thinking, and many students exercise their skills through game design activities. [47] researched that students should be encouraged in learning computational problem solving through a railroad simulation game activity. Based on this study, we noted that most studies applied and suggested that CT skills can be enhanced through game development and robotic design. Furthermore, the students computational thinking can not only be achieved through game-based or robotic design but should be integrated in a variety of designs in the learning of CT [48]. To broaden the thinking of students, we suggested that a variety of mobile application development needs to be implemented into the learning of CT. This approach will encourage students not only in game or robotic

activities but to learn and develop new apps through CT skills.[49] supports this approach and suggests that learning is most effective when students experience and discover new things for themselves. Thus, our colleagues' future plans are to conduct experimental research to identify how students can develop mobile applications through the MADLC model by incorporating the elements of CT.

VI. CONCLUSION

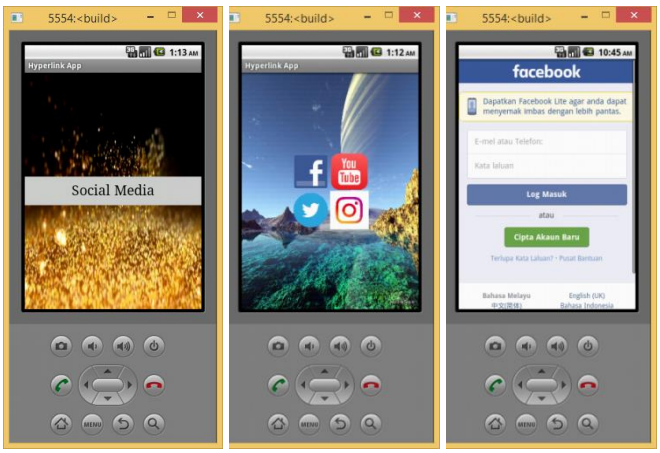
The transformation of the world economy from economies based on manufacturing to increased globalization and advances in technology have not only changed the knowledge and skills that students need to learn, but also revolutionize learning methods. From this revolution the students are constantly improving their self-esteem to compete in the work world. Computational thinking skills are also growing in their importance. In this paper, we incorporated the CT skills, namely Abstraction, Algorithm, Decomposition, Pattern Recognition and Evaluation into the MADLC model. This development is expected to encourage students to develop the CT skills needed by their future employers and at the same time produce mobile application developers. Thus, this paper gives two different benefits in one category, that is to learn CT and generate mobile application developers. All of the experts we interviewed regarding computational thinking stated that elements of computational thinking are able to be integrated into mobile application module development. From the interviews of all experts, we identified the appropriate CT elements that could be integrated into the MADLC model, namely abstraction, algorithm, decomposition, pattern recognition and evaluation.

APPENDIX

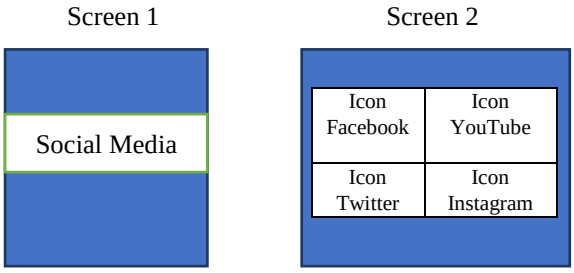
HYPERLINK APP

1.0 Identification Stage

This activity is about integrating elements of computational thinking skills to develop leaners' mobile app namely 'Hyperlink App'. 'Hyperlink App' refers to a link to a screen or a related page contained in a button. This App is simplified to facilitate opening social media such as **FACEBOOK**, **INSTAGRAM**, **TWITTER** and **YOUTUBE** from an app as shown in the diagram below:



i. Abstraction (Element of computational thinking skills)



Relevant Things	Irrelevant Things	Relevant Things	Irrelevant Things
i. Button ii. Name of button iii. Code (Screen 2) iv. Background image	i. Size of button ii. Properties of button iii. Image	i. Button (Four) ii. Icon of the buttons iii. Code	i. Speed of the internet ii. Brand

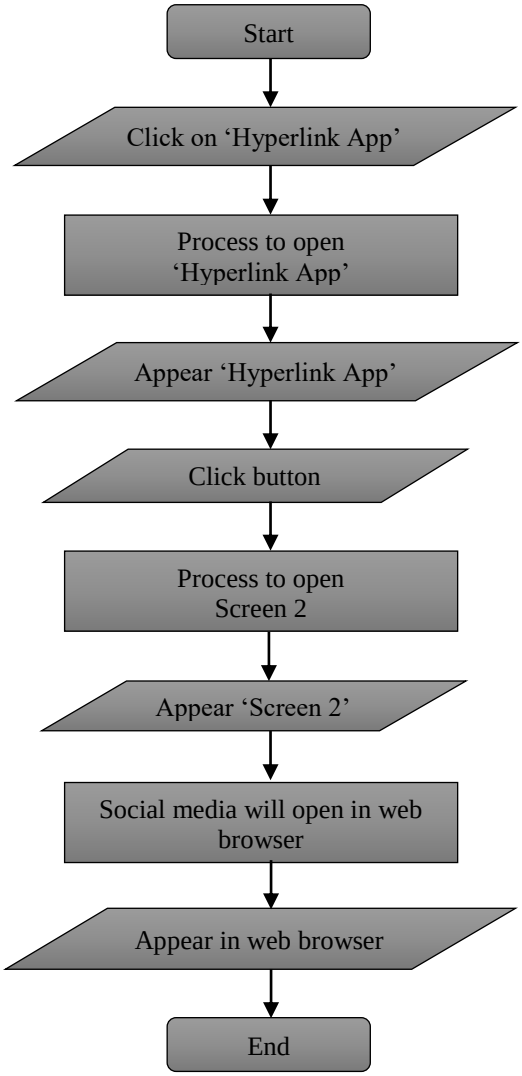
2.0 Design Stage

i. Algorithm (Element of computational thinking skills)

a) Pseudocode

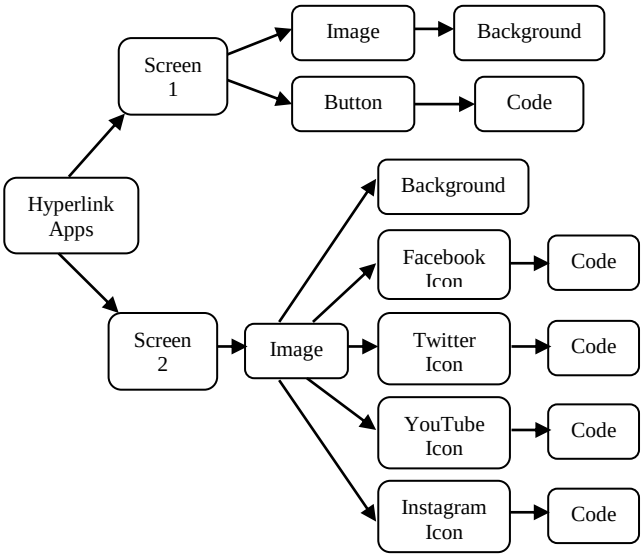
Step 1: Start
Step 2: Click on 'Hyperlink App' (input)
Step 3: Appear 'Hyperlink App'
Step 4: Click on name of the button 'Social Media'
Step 5: Screen 2 Appears
Step 6: Click on any social media icon
Step 7: Social media appears in web browser
Step 10: End

b) Flow chart



ii. Decomposition (Element of computational thinking skills)

Decomposition in computational thinking means breaking the complex problem into smaller problems that can be easily managed and understood. In order to break into small parts, horizontal hierarchy diagrams can be used. In the development of mobile application hyperlink there are two screens as shown below:

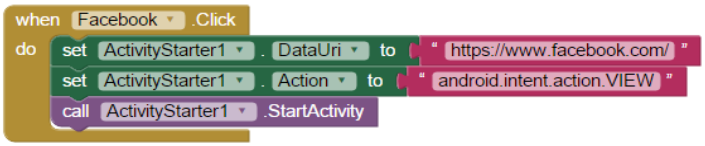


iii. Pattern Recognition (Element of computational thinking skills)

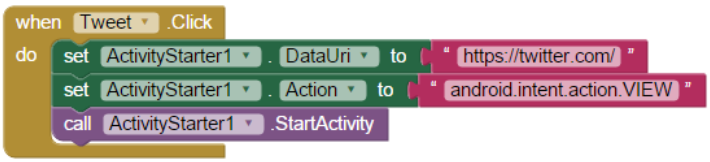
Pattern Recognition is a process of finding similarities in small parts when solving complex problems by using decomposition. Here similar design of block code is used to develop mobile application completely as shown below:

a. Screen 1 Block code

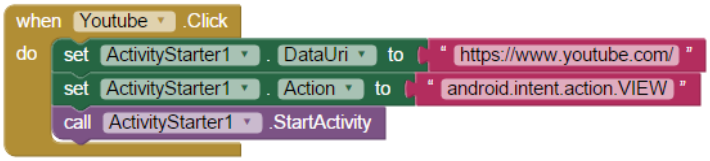
b. Screen 2 Block code for FB



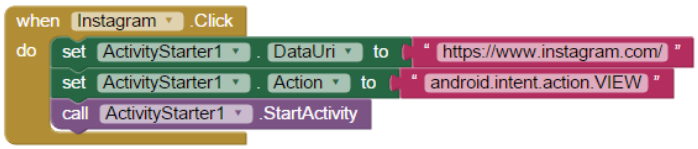
c. Screen 2 Block code for Twitter



d. Screen 2 Block code for YouTube



e. Screen 2 Block code for Instagram



3.0 Development Stage

Step by step to develop **'Hyperlink_App'** through App Inventor.

4.0 Prototyping Stage

In this stage, the application will be tested by experts to check whether it has met the requirements before being forwarded to users. Therefore, once the prototype is developed, it must be shown to the lecturer for the evaluation process.

a. Evaluation (Element of computational thinking skills) - For rubric form, please refer to **MIT App Inventor Project Rubric.**

5.0 Testing Stage

Testing is one of the most important stage in this model. Thus, testing must be carried out rigorously with targeted users through real devices.

a. Evaluation (Element of computational thinking skills)

Choose some users at random and ask questions to ascertain that the built-in mobile apps achieve the objective. If there are weaknesses in the mobile app, make the necessary improvements. For this

process, you can conduct semi-structured interviews with the target users and examples of questions are given below:

1. Is it user friendly?
2. Is this application easy to understand?
3. Does navigation within these apps take longer to produce the display?
4. Do you understand all the functions of the buttons and the menus shown in this app?
5. Do you like this application? (If Yes or No, ask why?)
6. Is there any improvement I should do in this application?

6.0 Deployment Stage

The final phase of the development process is Deployment. After the test is completed, then the applications are uploaded to the app stores for user to use it.

7.0 Maintenance Stage

Maintenance, which is a continuous process is the last stage of this model to make improvements according to the user output.

REFERENCES

1. [1] Rajendran, "Pengajaran kemahiran berfikir aras tinggi : Kesediaan guru mengendalikan proses pengajaran pembelajaran," in *Seminar Projek KBKK: Poster Warisan-Pendidikan-Wawasan 2001*, 2001, pp. 1–13.
2. [2] W. Ismail, W. O. Ali Saifuddin, and H. Noraini, "Critical thinking and problem solving skills among engineering students at public universities in Malaysia," in*Proc. - 2017 7th World Eng. Educ. Forum, WEEF 2017- Conjunction with 7th Reg. Conf. Eng. Educ. Res. High. Educ. 2017, RCEE RHEd 2017, 1st Int. STEAM Educ. Conf. STEAMEC 201*, 2018, pp. 262–267.
3. [3] B. Kules, "Computational thinking is critical thinking : Connecting to university discourse , goals , and learning outcomes," in Proceedings of the 79th ASIS&T Annual Meeting: Creating Knowledge, Enhancing Lives through Information & Technology, 2016, pp. 92.
4. [4] W. Nor, N. M. Arsad, O. Othman, L. Halim, M. S. Rasul, K. Osman, and Z. Iksan, "Fostering students' 21st century skills through Project Oriented Problem Based Learning (POPBL) in integrated STEM education program," *Asia-Pacific Forum on Science Learning and Teaching*, vol. 17, no. 1, pp. 1-18, 2016.
5. [5] Bernama, "Computational thinking, computer science to be taught in school next year," in*Bernama*, 2016.
6. [6] U. L. Ling, T. C. Saibin, J. Labadin, and N. A. Aziz, "Preliminary investigation: Teachers' perception on computational thinking concepts," *J. Telecommun. Electron. Comput. Eng.*, vol. 9, no. 2, pp. 2289–8131, 2017.
7. [7] S. Kassan, K. F. Looi, and Y. M. Tham, *Asas Sains Komputer*. 2016.
8. [8] B. C. Czerkawski and E. W. Lyman, "Exploring issues about computational thinking in higher education," *TechTrends*, vol. 59, no. 2, pp. 57–65, 2015.
9. [9] A. Pacific, "The mobile economy," 2016.
10. [10] J. Lockwood and A. Mooney, "Computational thinking in education : Where does it fit? A systematic literary review Table of Contents," pp. 1–58, 2017.
11. [11] M. Romero, A. Lepage, and B. Lille, "Computational thinking development through creative programming in higher education," *Int. J. Educ. Technol. High. Educ.*, vol. 14, no. 1, p. 42, 2017.
12. [12] J. M. Wing, "Computational thinking," *Commun. ACM*, vol. 49, no. 3, pp. 33–35, 2006.
13. [13] L. Perkovi, A. Settle, and J. Jones, "A framework for computational thinking across the curriculum," in *Proceedings of the Fifteenth Annual Conference on Innovation and Technology in Computer Science Education*, 2010, pp. 123–127.
14. [14] D. Hickmott, E. Prieto-Rodriguez, and K. Holmes, "A scoping review of studies on computational thinking in K–12 mathematics classrooms," *Digit. Exp. Math. Educ.*, vol. 4, no. 1, pp. 48–69, 2018.
15. [15] P. J. Denning, "Beyond computational thinking," 2009.
16. [16] J. J. Lu and G. H. L. Fletcher, "Thinking about computational thinking," in *Proceedings of the 40th ACM technical symposium on Computer science education*, 2009, pp. 260–264.
17. [17] B. Zhong, Q. Wang, J. Chen, and Y. Li, "An exploration of three-dimensional integrated assessment for computational thinking," *J. Educ. Comput. Res.*, vol. 53, no. 4, pp. 562–590, 2015.
18. [18] National Academics, *Report of a Workshop on The Scope and Nature of Computational Thinking*. 2010.
19. [19] A. V. Aho, "Computation and computational thinking," *Comput. J.*, vol. 55, no. 7, pp. 832–835, 2012.
20. [20] A. Yadav, H. Hong, and C. Stephenson, "Computational thinking for all : Pedagogical approaches to embedding 21st century problem solving in K-12 classrooms," *TechTrends*, pp. 565–568, 2016.
21. [21] D. D. Riley and K. A. Hunt, *Computational Thinking for the Modern Problem Solver*. CRC Press, 2014.
22. [22] M. M. Sysło and A. B. Kwiatkowska, "Introducing a new computer science curriculum for all school levels in Poland," in *International Conference on Informatics in Schools: Situation, Evolution, and Perspectives*, 2015, pp. 141–154.
23. [23] S. Y. Lye, J. Hwee, and L. Koh, "Computers in human behavior review on teaching and learning of computational thinking through programming : What is next for K-12 ?," *Comput. Human Behav.*, vol. 41, pp. 51–61, 2014.
24. [24] S. I. Swaid, "Bringing computational thinking to STEM education," *Procedia Manuf.*, vol. 3, no. Ahfe, pp. 3657–3662, 2015.
25. [25] L. W. Anderson, D. R. Krathwohl, and B. S. Bloom, *A Taxonomy for Learning, Teaching, and Assessing: A revision of Bloom's Taxonomy of Educational Objectives*. Longman, 2001.
26. [26] P. B. Henderson, T. J. Cortina, and J. M. Wing, "Computational thinking," in *Proceedings of the 38th SIGCSE technical Symposium on Computer Science Education*, 2007, pp. 195–196.
27. [27] P. P. Curzon, M. Dorling, T. Ng, C. Selby, and J. Woollard, "Developing computational thinking in the classroom: A framework," *Comput. Sch.*, 2014.
28. [28] C. Kazimoglu, M. Kiernan, L. Bacon, and L. Mackinnon, "Learning programming at the computational thinking level via digital game-play," *Procedia - Procedia Comput. Sci.*, vol. 9, no. 0, pp. 522–531, 2012.
29. [29] J. Black, J. Brodie, P. Curzon, C. Myketiak, P. W. McOwan, and L. R. Meagher, "Making computing interesting to school students," in*Proc. 18th ACM Conf. Innov. Technol. Comput. Sci. Educ. - ITiCSE '13*, no. July, 2013, pp. 255.
30. [30] M. G. Saudelli and K. Ciampa, "Exploring the role of TPACK and teacher self-efficacy: An ethnographic case study of three iPad language arts classes," *J. Technol. Pedagog. Educ.*, vol. 25, no. 2, pp. 227–247, 2015.
31. [31] L. Breslow, "The pedagogy and pleasures of teaching a 21st-century skill," *Eur. J. Educ.*, vol. 50, no. 4, pp. 420–439, 2015.
32. [32] IPGKPM, "Modul TMK dan pemikiran komputasional untuk KSSR," *IPGKPM*, 2016. [Online]. Available: http://www.ipgkpm.edu.my/portal2/news.php?readmore=32. [Accessed: 13-Oct-2017].
33. [33] M. Mohaghegh and M. Mccauley, "Computational thinking : The skill set of the 21st century," vol. 7, no. 3, pp. 1524–1530, 2016.
34. [34] Z. Ahmad, "Critical thinking skills, creative thinking skills and problem-solving skills needed by employers," 2016.
35. [35] MIHRM, "Creativity, problem solving & leadership skills," 2017. [Online]. Available: http://mihrm.com/creativity-problem-solving-leadership-skills/. [Accessed: 12-Oct-2017].
36. [36] E. Ak and M. Güvendi, "Assessment of the degree to which primary school teachers use alternative assessment and evaluation methods," *Procedia - Soc. Behav. Sci.*, vol. 2, no. 2, pp. 5599–5604, 2010.
37. [37] NMC, *The report of the 21st century literacy summit*. Adobe Systems, Incorporated, 2015.
38. [38] J. Dai, J. Teng, and X. Bai, "Mobile phone based drunk driving detection," in *2010 4th International Conference on Pervasive Computing Technologies for Healthcare*,2010, pp. 1–8.
39. [39] C. Tucker, R. Tucker, and J. Zheng, "StopWatcher: A mobile application to improve stop sign awareness for driving safety," *Int. J. Veh. Technol.*, vol. 2012, 2012.
40. [40] MCMC, "Hand phone user survey," 2014.
41. [41] M. E. Khamlichi, "The

history of android," 2015. [Online]. Available: https://www.unixmen.com/author/pirat9/. [Accessed: 12-Nov-2017].
42. [42] N. A. M. Fathi, M. Hashim, N. Ibrahim, "Applying mobile application development life cycle in the development of fasting tracker android application," *e-Journal,Penyelidikan dan Inov.*, vol. 4, no. 2, pp. 267–284, 2017.
43. [43] T. Vithani, A. Kumar, Member, and Iaeng, "Modeling the mobile application development," in *International MultiConference of Engineers and Computer Scientists*, 2014, vol. I, pp. 1–5.
44. [44] J. W. Creswell, *Educational research: planning, conducting, and evaluating quantitative and qualitative research*, 5th ed. Pearson, 2015.
45. [45] S. Atmatzidou and S. Demetriadis, "Advancing students' computational thinking skills through educational robotics : A study on age and gender relevant differences," *Rob. Auton. Syst.*, vol. 75, pp. 661–670, 2016.
46. [46] A. K. Hoover *et al.*, "Assessing computational thinking in students' game designs," *Proc. 2016 Annu. Symp. Comput. Interact. Play Companion Ext. Abstr. - CHI Play Companion '16*, no. October 2017, pp. 173–179, 2016.
47. [47] C. C. Liu, Y. B. Cheng, and C. W. Huang, "The effect of simulation games on the learning of computational problem solving," *Comput. Educ.*, vol. 57, no. 3, pp. 1907–1918, 2011.
48. [48] Z. Wang, J. Liu, C. Gu, Q. Hu, and X. Wen, "Research of computational thinking-driven teaching and innovative practice pattern," 2015.
49. [49] S. Papert, "Situating constructionism," *Constructionism*, pp. 1–11, 1991.

AUTHORS PROFILE

A PhD student at the Faculty of Education, UniversitiKebangsaan Malaysia who conducts research into computational thinking as well as mobile application development for undergraduates. He is also a lecturer in IT, specifically e-learning, computational thinking, mathematical thinking, Internet of Things (IoT), networking and programming languages (PYTHON, JAVA). This specialization is in the scope of his research.

Dr Siti Fatimah BtMohd Yassin is the Head of the Search & Talent Management Unit of Pusat PERMATApintar Negara, UKM and also senior lecturer at the Faculty of Education, UniversitiKebangsaan Malaysia. She has published high quality papers in various types of international journal. Her research interests are computer education, computer software development and technology education.

Dr. Farizabinti Khalid is a senior lecturer at the Faculty of Education, UniversitiKebangsaan Malaysia. She received her PhD from The University of Nottingham in the area of Instructional Technology. Her research interests are e-learning, online communities of practice and emerging technologies for educational purposes. She is also a life-member of the Qualitative Research Association of Malaysia (QRAM) and is currently the Deputy Secretary of Mobile Learning Association of Malaysia.