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Model component analysis of computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduates students

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Abstract

This study aimed to 1) examine and analyze the model components of computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students; and 2) assess and certify the suitability of such model using specifically related documents and studies. The employed instruments were 1) a learning management plan of the model; 2) an assessment form on ICT skills; and 3) an assessment form for products of the work. The findings indicated that through 4 analyzed steps of learning activities, there were 13 components of computational-thinking STEM Education. Furthermore, through 2 analyzed dimensions using the subjective assessment form on ICT skills testing scientific, technological, engineering, and mathematical knowledge; there were 10 components and 14 variables. The acquired data were further planned to be determined during the next focus group discussion of experts in various disciplines.

Keywords: STEM Education's model component analysis, computational thinking, information and communication technology skills

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1. Introduction

Presently, the global community has been paying immense attention to the use of information and communication technology (ICT). Various ICT applications have been deployed on economic, social, and educational developments to advance the evolution. UNESCO has also issued certain policies which gives a sense of direction to the future of global development and offers a venue for sovereign leaders to seek counsel from one another on how to sustainably develop the earth. Sustainability, in the context of global development, refers to a development in response to the needs of the current-generation people in a sense that it would not diminish or obstruct those of the next generation from responding to their future needs [1]. The more ICT-ready the countries are, the higher potential they have to be developed and advanced. Interestingly, this creates an even larger gap between the ICT-ready ones and the not ready ones. On education, ICT has also been playing a more vital role to it as it can serve multiple educational purposes from being a learning facility, knowledge exploration tool, to a measure to create new bodies of knowledge. For that, educational management should be adjusted in response to the digital-era dynamics.

STEM education is a curriculum designed provides an education using four disciplines: science, technology, engineering, and mathematics [2] in an interdisciplinary and applied manner [3]. Instead of teaching these four separately, STEM creates a cohesive learning out of them using real-world applications [4]. Though the United States has historically been a leader in these fields [5- 7], fewer students have been focusing on these recently [8]. These demands require people with the necessary knowledge and skills in science and technology that help students develop the essential and vital 21st-century skills. The Institute for the Future (IFTF) is an independent, nonprofit, and strategic organization whose job is to identify trends and essential future professional skills that are expected to emerge in 2020. In researching this topic, IFTF's foundational forecasts in areas as diverse as education, technology, demographics, work, and health. This content was enriched and vetted at a workshop that brought together experts from a wide range of disciplines and professional backgrounds. There are a number of things expected to change by 2020 [9] including increased longevity, the heightened role that technology and computation will play in our personal and professional lives, and intensified globalization. Simply put, the

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world is finding ways to do things better and to get more out of it. Optimistically, it is possible for us to experience an ñimprovedò society by 2020. The social and economic impact of technology is rapid and wide. The speed and volume of information have been increasing at an exponential rate. With the internet of things, the digital and physical worlds will soon be inseparable creating exciting possibilities. Simultaneously, however, the phenomenon might also bring uncertainty.[10] World Economic Forum (WEF) published a comprehensive report on the Industrial Internet which indicates that in the next 10 years, the Internet of Things (IoT) revolution will substantially transform manufacturing, energy, agriculture, transportation, and other industrial sectors of the economy. Furthermore, it is also projected to fundamentally shift the way people work involving new interactions between humans and machines. Digital intelligence or ñDQò is the set of social, emotional and cognitive abilities that would facilitate individuals to confront the forthcoming challenges and adapt to the influences imposed by the ñdigital lifeò. These abilities include eight interconnected dimensions: 1) Digital identity: the ability to create and manage a personôs online identity and reputation. This also includes the awareness of an online character and management of the short-term and long-term effects of the online presence; 2) Digital use: the ability to operate and utilize digital devices and media i.e. the control to achieve a healthy balance between online and offline life online and offline; 3) Digital safety: the ability to manage online (e.g. cyberbullying, extremism) as well as problematic content (e.g. disturbance and profanity), and control them) 4. Digital security: the ability to detect online threats (e.g. hacking, phishing, scams, virus, and malware), understand best practices, and employ appropriate security measures against them; 5) Digital emotional intelligence: the ability to feel empathetic and promote positive online relationships; 6) Digital communication: the ability to communicate and work with others using through digital means; 7) Digital rights: the ability to understand and maintain personal and legal rights, including the rights to privacy, intellectual property, freedom of speech, and protection from hate speech; and 8) Digital literacy: the ability to search, assess, use, distribute, and create content and competency in computational thinking. Dr. Krissanapong Kirtikara, the Deputy Minister of Education, Ministry of Education [11] asserted that the theoretical, computational, and experimental results of an ongoing investigation revealed 10 skills: 1) Sense-making: the ability to comprehend a deeper meaning of an expression; 2) Social intelligence: the ability to connect with others in a profound manner and sense or stimulate reactions; 3) Novel and adaptive thinking: the capacity to think and invent solutions outside the box; 4) Cross cultural competencies: the ability to work in different cultural environments; 5) Computational thinking: the ability to create an abstract concept out of vast data and understand data-based reasoning; 6) New media literacy: the ability to critically assess and develop content using new forms of media, and achieve a persuasive communication through such media; 7) Transdisciplinary: the ability to understand and literate concepts across multiple disciplines; 8) Design mindset: the ability innovate or develop tasks for desired outcomes; 9) Cognitive load management: the ability to sort and filter data by relevance and maximize cognitive functioning using tools and techniques; and 10) Virtual collaboration: the ability to work as part of a virtual team to produce an outcome, drive an engagement, and demonstrate a presence. In the context of new opportunities and the changing of the social development needs of older workers, large investment projects (Mega Projects), such as water management system, waste management, high-speed train, and road network between the country's digital economy should be introduced. Another effort in science should also be fostered. Technology and innovation should be consistent with the direction of the National Reform Council (NRC).

The International Society for Technology in Education (ISTE) has invented a set of comprehensive performance standards for the ICT knowledge and skills in learning, teaching, and school administration (ISTE, 2002). The rationales and developmental contexts were interwoven based on the standards themselves signifying a creative and innovative ability [12]. ICT Literacy is an essential skill in the 21st century [13, 14] and people of all educational levels from kindergarten to university should learn these the 3R x 7C [15] skills.

The 21st centuryôs education should promote these four aspects: 1) information literacy; 2) media literacy; 3) information and communication technologies (ICT); and 4) computational thinking [16]. With these requirements in mind, providing higher-level education can be challenging if the lecturers would desire to drive changes [17, 18]. To incorporate these requirements in the teaching, the learning management requires a model design. As the teaching will affect the learning, planning is extremely essential. Another important requirement to ensure success is that lecturers should be trained and comfortable in implementing the ICT. The design should be specific about what roles should the teachers have as they are the crucial players in the process [19] as for whether they would employ the technology is depending on their perceptions of the contributing benefits the technology has to the process of teaching and learning.

As changes occur very rapidly and pose various challenges as mentioned, the researchers found that it was necessary to examine the supporting factors for computational-thinking STEM education as the identified factors would guide and enhance the information and communication technology skills for undergraduates.

2. Materials and methods

I. Objectives

1. To examine and analyze the model components of computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students; and
2. To assess and certify the suitability of computational-thinking STEM Education model in enhancing the ICT literacy skills for the 21st-century undergraduate students

II. Methodology

A. Population and Sample

1. The population of the study was the experts on STEM Education, computational-thinking, and enhancement of information and communication technology skills;
2. The samples comprised 9 experts on STEM Education, computational-thinking, and enhancement of information and communication technology skills who were selected through purposive sampling provided that the samples must be either an academic employee or a lecturer with a doctoral degree or with a relevant experience.
3. Variables:

Independent variable: the examination and analysis of model components of computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students;

Dependent variable: the learning management framework of the computational-thinking STEM Education

B. Method

The researchers divided the study into two phases:

Phase 1: To examine the supporting factors for the learning management of the computational-thinking STEM Education, the following steps were employed:

1. Documents and research papers composed during 2011-2016 which are related to the learning management of the computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students were employed to define the framework and basic concepts of the study. Concepts, principles, and related subject matters were reviewed.

The researchers employed the following instruments:

1.1 The learning management plan for the learning management of the computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students was designed to manage all the learning plans. A total of five sub-plans were utilized with the following teaching steps and educational activities related to computational-thinking STEM Education:

Step 1: The aim is for the students to identify scientific, technological, engineering, and mathematical problems. During this step, the instructor would present a problematic situation, let the students work together to brainstorm and summarize the problems, and divide the problems into smaller categories so that they can be managed more easily. The divisions may include identifications such as disciplinary search terms in science, technology, engineering, and mathematics.

Step 2: The aim is for the students to describe and apply their knowledge of science, technology, engineering and math in different situations. The students learn and plan together to solve the problems in various situations using bodies of knowledge they learned from the four dimensions: science, technology, engineering and mathematics. Presentations and along with many other ways should be employed and identify the obstacles. Avoid confronting the obstacles and try to select an easier presenting approach.

Step 3: The aim is for the students to reflect the issues they learn on science, technology, and engineering. Science is the process that would allow the students to create the work piece, plan a series of steps to solve the problem, perhaps in a form of a reasoning and concluding diagram or flowchart, and recognize the pattern of the subgroups and problems. In short, science is expected to help the students can work more easily and quickly.

Step 4: The aim is for the students to summarize and evaluate the work piece by presenting and summarizing it using the discovered scientific, technological, engineering, and mathematical methods. The work should further be applied to solve the problem and the results should be evaluated to synthesize further suggestions.

1.2 Subjective measures on the competencies of information and communication technology skills were implemented to assess knowledge of science, technology, engineering, and mathematics. The six analyses were as follows:

1.2.1 The ability to skillfully and carefully create, innovate, and communicate in search of information;

1.2.2 The ability to communicate and work together which include information query and classification;

1.2.3 The ability to find information, interpret data, and use information tools;

1.2.4 The ability to fluently, prudently and flexibly develop the evaluation criteria to determine the appropriate data;

Table 1 : The model components on the learning management comprise the steps of learning activities used in computational-thinking STEM Education:

Aspects	Components
1. Identify issues of science, technology, engineering, and mathematics	1. To appropriately brainstorm and summarize of the problems in science, technology, engineering, and mathematics; 2. To appropriately divide problems into smaller categories; and 3. To appropriately ease the data management
2. Discuss the knowledge of science, technology, engineering, and mathematics to further be used in different situations	1. To appropriately plan and solve problems using knowledge of science, technology, engineering, and mathematics; 2. To employ multiple presenting approaches; 3. To properly filter out undesired issues; and 4. To appropriately select methods for the model design or innovate new solutions
3. Reflect ideas on science, technology, engineering, and mathematics	1. To appropriately create a model based on the designed plan with a step-by-step process; 2. To logically implement the solution flowcharts leading to proper conclusions; 3. To be able to recognize the similarities of sub-plans and issues; and 4. To appropriately create a model with ease and speed
4. Summary and model assessment	1. To appropriately use knowledge of science, technology, engineering and mathematics to correct the presentations and establish a summary; 2. To appropriately utilize a solution, evaluate the results, and generate suggestions

1.2.5 The ability to be a digital citizen who designs and applies a certain information technology for improvements;

1.2.6 The technological capabilities which include the ability to select the appropriate communication method and application.

1.3 The rubric score assessment comprising four content aspects were found to be useful in applications, technical planning, presentation, and presentation listening. Upon the completion of the rubric assessment, the results were submitted to the thesis advisor for a further verification and adjustment prior to a further use.

Phase 2: The assessment and certification of the suitability of the computational-thinking STEM Education model were evaluated during this phase and the procedures are as follows:

2.1 The Model Component Analysis

After analyzing the model components of the computational-thinking STEM Educationôs learning management, the experts offer a learning form to the nine experts who were either an academic employee or a lecturer with a doctoral degree or with a relevant experience. The form was then evaluated using a 5 - score rating scale.

2.1.1 The learning management of the computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students

2.1.2 The assessment certification of the suitability of the teaching patterns was conducted using a 5-score evaluation rating which are interpreted as the learning format being as follows [20]:

4.51-5.00 for most suitable;
3.51-4.50 for highly suitable;
2.51-3.50for moderately suitable;
1.51-2.50 for poorly suitable;
1.0-1.50 for not suitable

2.2 According to the expertsô suggestions, the model was improved.

3. Results and discussion

The examination and analysis of the model components of computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students were conducted using materials and related research. The following model components were identified:

1. Identify issues of science, technology, engineering, and mathematics;
2. Discuss the knowledge of science, technology, engineering, and mathematics to further be used in different situations;
3. Reflect ideas on science, technology, engineering, and mathematics;
4. Draw a conclusion, evaluate the work, evaluate it, and create a recommendation.

The four dimensions comprised 14 elements as described in Table 1:

Table 2: Subjective measures on the competencies of information and communication technology skills were implemented to assess knowledge of science, technology, engineering, and mathematics

Aspects	Components	Variables
1. The skills	1. Creativity and innovation	1. The ability to fluently and carefully search for the information
	2. The ability to communicate and work together	1. The ability to fluently and carefully retrieve the information; and 2. The ability to fluently and carefully classify the information;
	3. The ability to search for the information	1. The ability to interpret the displayed information; and 2. The ability to fluently and carefully use information technology tools
	4. The ability to think	1. To carefully, fluently, and resiliently define and establish evaluation criteria to suit the data
	5. The ability to be a digital citizen who designs and applies a certain information technology for improvements	1. The ability to fluently, prudently and flexibly develop the evaluation criteria to determine the appropriate data; 2. The applications of information technology; 3. The ability to prudently and flexibly apply the appropriate information; and 4. The ability to prudently and flexibly update the appropriate information
	6. Technological capabilities	1. The ability to select and apply proper information and communications
2. Model assessment	1. Content and application aspects	1. Analyze ideas and aggregate contents from the model
	2. Planning preparation aspect	1. Analysis of the aggregated plan after applying to the model
	3. Technical aspect	1. Analysis of the aggregated technical ideas from the model
	4. Presentation and recommendation aspects	1. Analysis of the aggregated presentation and feedback obtained from the model
2 **aspects**	1 **component**	14 **variables**

4. Conclusions

The results showed that the examination and analysis of model components of computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students from the aspect of learning-management model components consisted of 4 steps of learning activities including 1) 4 steps on the learning management and 13 components of computational-thinking STEM Education; and 2) 2 aspects, 10 elements, and 14 variables on ability measurements of information and communication technology skills subjective to the knowledge of science, technology, engineering, and mathematics. The results were to be used by the focus group discussion of experts in the next phase.

5. Suggestions for bringing research results to the users

To apply the examination and analysis of model components of computational-thinking STEM Education in enhancing the ICT literacy skills for the 21st-century undergraduate students, it should be analyzed carefully. Or add in statistical data analysis.

6. Recommendations for further research

Components of the ICT literacy skill with the modern of techniques and CFA statistics for students should be considered implementing in the next studies.

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