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STEM LEARNING SYSTEM WITH THE INTERNET OF THINGS THROUGH CLOUD LEARNING TO DEVELOP THE DIGITAL LITERACY AND CREATIVE PRODUCTS OF HIGHER EDUCATION STUDENTS IN THE 21ST CENTURY

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ABSTRACT

This research aimed to study the demonstration of STEM Learning System with the Internet of Things through cloud learning in three different objectives: 1) a comparison of the 'Digital Literacy' scores of students before and after the class, 2) a comparison of the 'Creative Product' scores of students with the standard (60 percent), and 3) a comparison of the 'Digital Literacy' scores of students before class, after class and after taking a 1-month class. The target of this research was a group of students who registered for the 'Embedded System and Application' subject in the 1st semester of the academic year 2021. A class of students registered for the 16-week at Southeast Bangkok College. The measures used in this research were 'Mean', 'Standard Deviation (S.D.)', One Sample t-test, Paired Sample t-test, and One Way Repeated Measure ANOVA. The research findings revealed that 1) Students had a higher mean digital literacy score of 5.667 after the class compared with before, at a significance level of .05. 2) Students had a mean higher creative product score of 8.306 compared with the standard score at a significance level of .05. 3) Students had higher digital literacy scores after completing 1-month class and after class than before taking the class, at a significance level of .05

Keywords: *STEM, Internet of Things, Cloud Learning, Digital Literacy, Creative Product.*

1. INTRODUCTION

At present, information and communication technology is being developed with the use of such aspects as the Internet of Things (IoT) in order to make people's life more convenient, and support the industrial, medical, agricultural and educational sectors [1], [15]. According to a previous statement, the Thai government decided to execute the 'Thailand 4.0' model to drive the country out of middle-income trap, and to move forward in terms of national economic development by focusing on a value-based economic system that could increase both the value and the potential of the manufacturing and service sectors. This model is to be the foundation of the Thai economic system through innovation, technology and creativity by developing the 'Internet of Things', providing knowledge and understanding to those who had opportunities to use them, and pointing out the benefits of using this type of technology [19].

STEM was a concept relating to educational management that integrates 4 interdisciplinary areas science, technology, engineering, and mathematics by applying knowledge in such a way as to solve actual problems in life [11], [16], as well as developing new processes or products that are beneficial individuals in terms of their working and personal lives. STEM learning management does not focus on memorizing theory, but on emphasizing the understanding of concepts and theories through actual practice, together with improving thinking skills by questioning, solving problems, searching for more information, analyzing new data and applying the knowledge obtained to use in daily life [11].

The Internet of Things (IoT) is a system that has altered how people live [20]. This system helped to connect devices and machines via internet networks in order to manage the transfer of data by embedding electronic devices in tools [21]. However, cloud processing was required for the IoT. Thus, cloud technology was implemented in class in the form of 'cloud learning'.

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Cloud learning is a learning model that applies a large IT computing infrastructure that is able to connect users over the internet via 'cloud technology' [7]. Cloud learning works with the aid of a cloud computing system that was created in the form of a web browser or application manager [13]. Cloud learning supports learning and teaching in terms of creating educational activity. It allows students to connect to the network anywhere and at anytime. It also acts as a medium which helps students and teachers communicate more easily [6]. Furthermore, cloud learning is a system that encourages students to use digital skills and develop creativity in their work.

Digital Literacy is an essential skill for students which supports teaching and learning in the 21st Century [22]. Technology is now used to assist people in satisfying their daily demands. Therefore, students' technological skills need to be improved by the education sector [12]. These include technology skills, particularly with regard to 1) digital access, 2) digital communication, and 3) digital safety [18].

Creative product refers to the production of an idea or artefact which has a unique identity that was created and designed by the creator [3], [17]. It could be in both tangible and intangible forms. The product of a creation that can solve a particular problem must be innovative and valuable to the creator, society and culture [17]. Hence, creativity could add to the value of a product.

Based on the previous statement, the educational sector must adapt itself to change that focuses on the integration of technology and innovation in the business and industrial sectors. Thus, the researcher decided to develop a STEM Learning System with the Internet of Things through Cloud Learning to develop the digital literacy and creative products of higher education students in the 21st Century in order to enhance the experience of human resources in terms of creating innovative products and increase skills leading to digital literacy, because recent advances in most popular sciences and technologies include cloud learning, the IoT, and STEM

2. RESEARCH QUESTION

How were the results of the STEM Learning System with the Internet of Things through cloud learning to develop the digital literacy and creative products of higher education students in the 21st Century?

3. RESEARCH OBJECTIVE

3.1 To compare the digital literacy scores of students before and after class.

3.2 To compare the creative product scores of students with the standard (60 percent).

3.3 To compare the digital literacy scores of students before class, after class and after taking a 1-month class.

4. RESEARCH METHODOLOGY

In this step, the researcher would like to consider 4 aspects. These are as follows:

4.1 The development of concept framework of STEM Learning System with the Internet of Things through Cloud Learning to develop the digital literacy and creative products of higher education students in the 21st Century.

The researcher studied, analyzed, synthesized and integrated publications related to STEM, the IoT, cloud learning, digital literacy, creative products, and current teaching and learning conditions. This was done in order to apply the collected data to the improvement of a STEM Learning System with the Internet of Things through Cloud Learning model. This process consisted of 8 steps and a number of different tools [4], [5], [11], [13], [22] as shown in Figure 1. The details of the above-mentioned model are as follows:

1. Problem identification

In this step, the teacher encouraged students to look for problems in their environment. The students then worked in groups brainstorming different issues. They summarized the issues that they would like to study, and presented what they would like to learn to the teacher. Next, the teacher gave suggestions regarding the presented issues. Moreover, the student groups could fix and adjust the details with regard to the issues that they wished to study.

2. Related Information Search

In this step, the student groups researched the information and concepts that were relevant to the issues that they wished to study. Additionally, the student groups summarized the options, feasibilities, advantages and disadvantages under the conditions and environments to solve problems, and improve the collected information.

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3. Plan

In this step, the student groups analyzed the gathered information and concepts in order to create plans, and establish timings, procedures, components and responsibilities. In addition, the student groups presented the plans to the teacher for advice and suggestions aimed at improving their plans.

4. Design

In this step, the student groups designed and created drafts and models related to the concepts that they had planned, and presented their models to the teacher in order to obtain further advice and suggestions.

5. Development

In this step, the student groups developed their creative works based on their designs. They then tested and improved their creative work by looking at each procedure.

6. Testing

In this step, the student groups presented the test of their creative works to the teacher. The teacher gave suggestions and recommendations following their presentation.

7. Present

In this step, the students had to design their presentation in terms of concepts, procedures, designs, creative work development, testing, results and suggestions in such a way that their creative work.

8. Reflection

In this step, the teacher made suggestions about the information and procedures related to the creative works that had been presented, in order to improve them further.

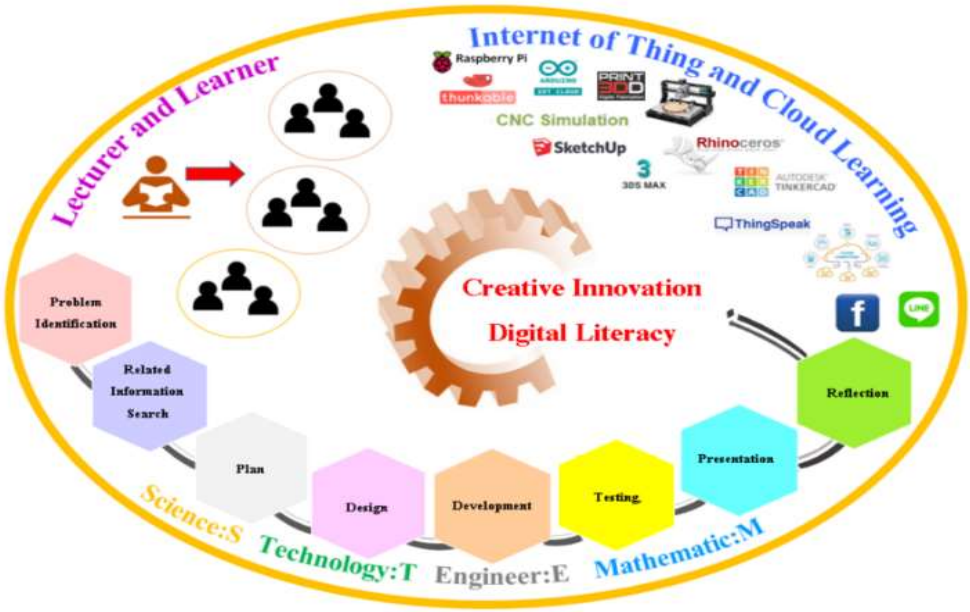

Figure 1: Concept framework.

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After the researcher had developed concept framework, the researcher created suitability evaluation tool of the concept framework of STEM Learning System with the Internet of Things through Cloud Learning, which consisted of 19 questions (18 close ended questions and 1 open ended question) for 3 experts with the characteristics as follows: 1. Educational qualifications higher than a master's degree, and 2. having at least 3 years of experience in educational administration or information technology in order to review quality of content validity tools by finding item-objective congruence index (IOC) that must have a value from 0.50 to 1.00 (if the assessment form was evaluated to be 1.00, this means all questions could be actually used effectively). After that, the researcher brought the tool that has been assessed for suitability to 5 experts with educational qualifications higher than a master's degree and at least 3 years of experience in educational administration or information technology to evaluate the suitability of this conceptual framework by using a 5-point Likert scale, Mean: ($\bar{x}$), and Standard Deviation (S.D.). The overall average assessment result of this conceptual framework was ranked as in highest level ($\bar{x}$ = 4.93, S.D. = 0.22). Therefore, the researcher could use the conceptual framework of STEM Learning System with the Internet of Things through Cloud Learning model as a model for making a system to support learning.

4.2 Research Hypothesis

In this study, the researcher considered 3 hypotheses as follows:
Hypothesis 1 : Students have higher digital literacy scores after class than before the class.
Hypothesis 2 : Students have higher creative product scores than the criteria (60 percent).
Hypothesis 3 : Students have higher digital literacy scores after class and after completing 1-month class than before class.

4.3 Population and Samples

The population of this study was a class of 36 students who registered for the 'Embedded System and Application' subject in the 1st Semester of the academic year 2020 at Southeast Bangkok College. This group of students made up the sample of this study.

4.4 Variables in this study

1. The dependent variable was 'STEM Learning System with the Internet of Things through Cloud Learning'.
2. The independent variables were digital literacy and creative product.

5. RESEARCH RESULTS

The details of the research hypotheses are as follows:

Hypothesis 1 : Students have higher digital literacy scores after class than before the class.

In the demonstration of the STEM Learning System with the Internet of Things through Cloud Learning, the researcher examined the students' knowledge with regard to digital literacy before the class began. At the end of the experiment their knowledge of digital literacy was again examined by using the same test series. Furthermore, this hypothesis was tested using a paired sample t-test as shown in Table 1.

Table 1: The examination results of digital literacy before and after class

Class	Amount	$\bar{x}$	S.D.	t	Sig
Before class	36	7.556	3.139	16.209**	.000
After class	36	13.222	3.673		

Note: ** P < .01

According to Table 1, before studying with STEM Learning System with the Internet of Things through Cloud Learning, 36 computer technology majored students that had registered for the 'Embedded System and Application' subject had a digital literacy score averaging 7.556, whereas the score after the class was 13.222 at a significance level of .05. The difference between the scores before and after the STEM Learning System with the Internet of Things through Cloud Learning was 5.666 which is consistent with the hypothesis 1.

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Hypothesis 2 : Students have higher creative product scores than the criteria (60 percent).

In STEM Learning System with the Internet of Things through Cloud Learning, the researcher required the students to create one creative product per group. The creative product was analyzed by 3 professors according to the developed assessment form to find the average scores with regard to the creative products of each student group. The policy of the Computer Technology major required students to have higher creative product scores than the stated criteria (60 percent). The second hypothesis was tested using the One Sample t-test as shown in Table 2.

According to Table 2, after students completed the lessons of STEM Learning System with the Internet of Things through Cloud Learning, the creative product was required to be created by each student group with the score of 26.306, whereas the required criteria score of Computer Technology was 18 (60 percent). The students' creative product scores were higher than the criteria at a significance level of .05. The student's creative product mean score was 8.306 more than the criteria, which supports hypothesis 2.

Table 2: The examination results of Creative product results with criteria

Score	$\bar{x}$	S.D.	Criteria	t	Sig
Creative Product	26.306	2.692	18.000	18.512**	.000

Note: ** P < .01

Hypothesis 3 : Students have higher digital literacy scores after class and after completing 1- month class than before class.

In the demonstration of STEM Learning System with the Internet of Things through Cloud Learning, the researcher arranged an examination to test students' knowledge with regard to digital literacy before starting the class. After completing the class, the researcher tested the students' knowledge with regard to digital literacy again. And, after completing 1-month class, the same test series was executed again to compare the results. Hypothesis 3 was tested with the use of a one-way repeated measure ANOVA as shown in Table 3.

According to Table 3, 36 computer technology students who registered 'Embedded System and Application' had 7.556 digital literacy scores before taking the class. After the class, the scores were changed to be 13.222. And, after completing a 1-month class, the students' scores were 17.278. Students' digital literacy scores before class, after class, and after completing 1-month class were different at the significant level of .05. After testing a pair of students, the results revealed that students' digital literacy score after completing 1-month class was more than both before sitting in class and after class 9.722 and 4.056, correspondingly. Additionally, the students' digital literacy score after class was 5.667 more than before class as shown in Figure 2, which was consistent to the hypothesis 3.

Table 3: Digital literacy scores before class, after class, and after completing 1-month class.

Class	$\bar{x}$	S.D.	Source of Variation	SS	df	MS	F	Posthoc
Before class	7.556	3.139	Inside the group					3 > 1,2
After class	13.222	3.673	Duration	1701.389	1	1701.389	135.766**	2 > 1
After completing a 1-month class	17.278	3.693	Error	438.611	35	12.532		

Note: Greenhouse-Geisser = .623 : Eta Squared = .795 : ** P < .01

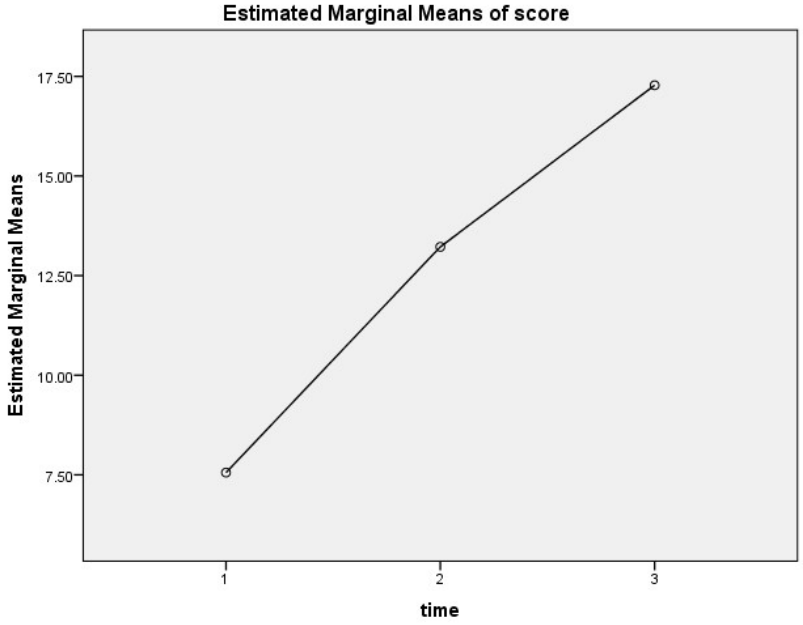

Figure 2: The students' scores of Digital Literacy were measured for 3 times; before class, after class, and after completing 1-month class.

From testing hypotheses 1-3. The researcher has made a table to summarize the hypothesis testing results as shown in Table 4:

Table 4: The results of the hypothesis 1-3

Hypothesis	*Results of hypothesis*
Hypothesis 1 : Students have higher digital literacy scores after class than before the class	Accept
Hypothesis 2 : Students have higher creative product scores than the criteria.	Accept
Hypothesis 3 : Students have higher digital literacy scores after class and after completing 1-month class than before class.	Accept

According to Table 4, the findings revealed that the 3 hypotheses were all accepted. This could be interpreted by suggesting that the STEM Learning System with the Internet of Things through Cloud Learning could help to increase the knowledge of digital literacy skills after taking the 1-month class for the students. Furthermore, the system also allowed students to create creative product that was better than the one specified in the criteria (60 percent)

6. DISCUSSION

The research findings posited that after attending the class, students had higher digital literacy scores than before attending the class at a significance level of .05. The STEM Learning System with the Internet of Things through Cloud Learning model increased the students' digital literacy (digital access, digital communication and digital safety) because students who enrolled into the system had to practice digital access, digital

communication and digital safety [18]. Learning the whole subject by connecting to the learning system while studying included communication between teachers and students through digital media. Additionally, through digital media, students were required to conduct research, communicate, and exchange information regarding the worksheets given by the teacher. Students were required to. This teaching and learning system also supported communication between teachers and students through digital media. Additionally, through digital media, students were required to conduct research, communicate, and exchange information regarding the worksheets given by the teacher. Furthermore, students must connect to the system using devices such as microcontrollers and system sensors. As students completed their STEM education with the use of the IoT using cloud learning technology, they developed their digital knowledge and skills which helped them to familiarize with the IoT as stated in the study of Hoon, Wang & Lawrie (2017) [8].

After completing 1-month class, students had higher digital literacy scores than after attending the class and before starting the class at a significance level of .05, because students had opportunities to practice digital access, digital communication and digital safety during the class. This caused the students to be familiar with the technology. Since digital technology (Ex. computer, internet, digital media and social network) is becoming more and more tangible in Thai culture nowadays, students could use digital literacy everyday to be more proficient than before and after the class, which could be utilized in their future careers.

The study results stated that the students had higher creative product scores than the criteria at a significance level of .05, because the STEM learning developed by the researcher consisted of different processes: Problem identification, Related Information Search, Plan, Design, Development, Testing, Present and Reflection [4], [5], [11], [13], [22]). The previously mentioned processes helped students to learn to apply the acquired knowledge to be able to complete creative product according to the policy of the Computer Technology major, which required students to have scores in excess of 60 percent, and be able to create innovative or creative products [10] that are related to the identity of South East Bangkok College (2018) towards the production of graduate professional practitioners in management and technology [9]. This is related to the study of Ahmed (2016) [2].

From this study, South East Bangkok College should conduct a policy that continuously supports teaching and learning in the form of STEM Learning System with the Internet of Things through Cloud Learning model in order to provide opportunities to every student to be proficient at technology and innovation to the point that they can utilize this proficiency in their future career to drive the country.

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