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STEM Learning Model Design Using IoT for Primary School Students

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ABSTRACT
Competence in the STEM field is increasingly needed in the face of the Industry 4.0 revolution. One inevitable learning tool is an IoT-based one. This study aims to examine the IoT-based STEM learning model for primary school students. The study was carried out using a qualitative inquiry method in a field laboratory setting. Referring to McGrath's classical circle, the study's data collection method could fit into realism field study and field experiment quadrant. Research participants were one research group consisting of two lecturers (Information Technology and Educational Psychology), two Information Technology students and three Psychology students as peer-group discussions. Experiments were conducted to compare the effective ways of using Digital Plant Growth Sensors. Data on nutrition, temperature, humidity, sunlight and physical measurements were collected. The study was carried out within 4 months. Each learning step was discussed intensively, and the notions found were assessed through an inter-rater. The whole inquiry process implements Vygotsky's theory. We found that STEM learning via IoT Digital Plant Growth Sensors has the potential to improve basic skills of recording, describing, and analyzing data which are basic proficiency requirement in Biology, Technology, Engineering, and Mathematics. Specifically, this learning model also has the potential to improve data literacy and simple statistics for basic education at primary school level.

Keywords: *STEM, IoT, Primary School Students, learning model, data literacy*

1. INTRODUCTION

The industrial revolution 4.0 changes the perspective on the use of technology. This growth is marked by the presence of the Internet of Things. The IoT concept brings a technological revolution to make devices and communications faster, smarter, and more informative [1]. IoT-element devices can be controlled remotely to perform desired actions. IoT also allows users to share information between devices over a network using standard communication protocols [2].

Competence in the STEM field is increasingly needed in the face of the Industry 4.0 revolution along the development of IoT. The development of the industrial 4.0 era forces all fields to compete to catch up. This has an impact on the STEM learning method in the field of education [3]. The development of STEM is certainly felt by elementary school students and is necessary to achieve success in college, career and STEM professional fields [4].

The STEM approach provides opportunities for prospective teachers, especially elementary school teachers to realize the concepts and principles of science, technology, engineering, and mathematics that are used in an integrated manner in the development of processes, products, and systems that can be used in everyday life [5].

STEM education is defined as an interdisciplinary approach to student learning in studying science, technology, engineering, and mathematics in school, at work, and globally to develop STEM literacy skills that can enable students to compete in the new knowledge-based economy era [6].

The influence of the 4.0 era makes elementary schools apply a learning method for STEM education that is in accordance with the latest technological developments. One example is the development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools [7].

Implementing a learning method requires teacher professional development in STEM knowledge to focus on improving content knowledge as a means of influencing teacher practice [8]. The principles that can be analyzed in the application of STEM into the teacher education curriculum are (a) creating a functional environment such as opportunities to engage in problem solving and cooperation, high cognitive demands; (b) provide opportunities for students to practice; (c) integrate STEM standards. The STEM curriculum is one of the foundations for integrating robotics into the elementary school curriculum. Teachers who teach robotics may be more open or positive during teaching if they meet teaching standards and the teacher has an intention to teach students. Characteristics of problem solving, cognitive demands and cooperation become aspects of the functional environment in implementing STEM curriculum [9].

The application of STEM for students can improve critical thinking skills [10], [11], add experience, increase enthusiasm, motivation, develop understanding of the engineering design process and the integration of science, technology, engineering, and mathematics that can be used to solve problems in the real world [12]. The application of STEM in improving critical thinking skills complements previous findings regarding thinking skills training [13].

This study aims to examine the IoT-based STEM learning model for primary school students. The design of the IoT-based STEM learning model is based on student experiences.

2. LITERATURE REVIEW

2.1. Internet of Things (IoT)

Internet of Things (IoT) is a technology that is useful in various sectors of life. The education sector is a strong candidate for the application of IoT [14]. Various efforts are being made in implementing IoT into the current educational curriculum aimed at making long-term behavior change [15]. The implementation of IoT as a topic of curriculum development is supported based on previous studies [16] which suggested that students' understanding of interdisciplinary instruction should be deepened so as to increase their attention in science, technology, engineering, and mathematics through computational thinking and data analysis in various fields.

Professional development can focus on implementing IoT in the curriculum by creating different types of robots such as basic cars, gyro boys, and cranes rather than single robotics designs and teachers will learn how to use and facilitate game design using different types of software in the next few years. The results of using this robot certainly encourage students to creatively make an innovative and unique game with the instructional scaffolding method, and help maintain students' learning motivation [17].

2.2. Multi-Level Framework of Technology Acceptance and Use (MFTAU)

In an effort to integrate IoT in the elementary school curriculum, the framework that can be considered is MFTAU (Multi-Level Framework of Technology Acceptance and Use). The MFTAU model is an approach developed by Venkatesh. This model integrates the results of theoretical analysis and presents them in the form of a multi-level framework. Through the MFTAU framework, the acceptance and use of technology is analyzed in terms of different levels of factors, the Higher-level Contextual Factors (HC) and Individual-level Contextual Factors (IC). These two levels theoretically affect the individual's intention to accept and use technology [18].

Individual-level Contextual Factors (IC) incorporates the moderating effects of age, gender, and experience in UTAUT [19]. Higher-level Contextual Factors (HC) includes the physical environment of the individual user that serves as the immediate context for the acceptance and use of the technology.

2.3. STEM Learning through IoT for Students

A study on the application of STEM for elementary school students by studying computer science, namely online coding, showed that students' self-concepts increased during STEM learning. Students quickly learn the lesson and enjoy the STEM activity. In addition, the use of computer science such as learning coding programs and playing games increases students' understanding of sequences, algorithms, debugging and loops. Students also experience increased concentration, find out more STEM concepts, form knowledge, and acquire decision-making ability. This development is of course also influenced by motivational factors from parental support on self-concept, student self-confidence. Parents also need to be aware of these learning activities during the intervention period of STEM activities. Schools also needs to provide training on parental activities that support students' intrinsic motivation in STEM and computer science content [17].

The application of STEM to students is done by forming a robotics/gaming club where students create a game/robot. The results of this application indicate that students are glad to be able to make the robot move and perform tasks combined with creativity connected with game development

from scratch. In addition, self-efficacy, computational thinking, and students' self-confidence increased during making video games. These findings are unique because they combine robots with innovative game designs and are not found in any literature [17], [20], [21].
Studies that integrate STEM in the curriculum prove that STEM learning has the potential to have a positive impact both in the learning atmosphere and in increasing student competence.

3. METHOD

The study was conducted using a qualitative inquiry method in a field laboratory setting. Referring to McGrath's classical circle [22], the study's data collection method could fit into realism field study and field experiment quadrant. Research participants were one research group consisting of two lecturers (Information Technology and Educational Psychology), two Information Technology students and three Psychology students as peer-group discussions.
Student participants examined the use of IoT in the form of Digital Plant Growth Sensors, on plants. Student participants tried several positions of placing sensors, and found the best placement method to produce accurate data.

Figure 1 Digital plant growth sensors and Mobile phone as IoT tool, STS IoT experimental laboratory

Figure 2 One of the experimental plants

Experiments were conducted to compare the effective ways of using Digital Plant Growth Sensors. Data on nutrition, temperature, humidity, sunlight and physical measurements were collected. The study was conducted within 4 months. Each learning step was discussed intensively, and the notions found were assessed through an inter-rater. The whole inquiry process implements Vygotsky's theory [23].

4. RESULT & FINDINGS

Through participant assessment and reflection on the use of IoT in STEM learning, researchers found various competencies that could potentially be improved in the learning process. Through the practice of using IoT Digital Plant Growth Sensors, students have the potential to acquire basic skills in: (a) record keeping; (b) describing; and (c) data analysis. These three skills are the basic skills needed in learning Biology, Technology, Engineering, and Mathematics. In particular, this learning model also has the potential to improve data literacy, and simple statistics for elementary school students.
The results of this study support previous research which found that students positively perceive STEM learning content after engaging in the STEM curriculum and students are motivated to engage [24]. Students experienced an increase in the ability to process knowledge, integration of knowledge content, and knowledge concepts [25]. Students consider STEM education as an instructive, creative and motivating method because students feel an increase in creativity and motivation towards learning and can contribute to career choice [26].
The research data obtained shows that the development of IoT-based technology can help hone learning competencies in the fields of Science, Technology, Engineering, and

mathematics. Table 1 shows the learning outcomes obtained in the preparatory activities.

Table 1 Learning Outcomes in Preparatory Activities

No	Activities	Learning Outcomes
1.	Prepare gardening equipment such as pots, shovels, seeds, soil, gloves, etc	- Knowledge of science, especially botany
2.	Calculating soil depth and counting seeds	- Mathematics skills
3.	Planting seeds in pots and Watering plants	- Knowledge of botanical concepts - Fine motor development
4.	Installing tools properly	The skill to put IoT in the right place

After the preparation phase was completed, participants conducted a trial of plant growth monitoring, and recorded self-reflection on the various competencies that may be achieved by the implementers of the activity. Table 2 shows the competencies that can be obtained through these monitoring activities.

Table 2 Learning Outcomes through plant growth monitoring activities

No	Activities	Learning Outcomes
1.	Using the app as to measure growth parameters	-Knowledge of application usage -Knowledge of the workings and sensors in IoT device -Knowledge of the meaning of the measured parameters
2	Touch and feel the soil, seeds and flowers	-Increased sensitivity of the sense of touch -Knowledge of the texture of an object
3	Observe the bright colors and different sizes of plants	-Increased sensitivity of the sense of sight
4	Pay attention to which plants need more sunlight, which require less water and how long they take to grow	-Knowledge of science, especially biology -Training to focus on an object -Training oneself to find information -Development of conscientious, diligent, hard working attitude - Ability to think inductively and deductively in concluding
5	Checking plant growth such as stem height and leaf width every 3 days using a ruler	-Diligent, hard working, thorough attitudes
6.	Taking care of seeds and plants every day, by watering and fertilizing	-Responsibility

This learning activity will have a positive impact and be an interesting experience for elementary school students. They may become interested in growing, caring for and learning about the vegetables they grow. Although in practice there are still many shortcomings, students will still be enthusiastic. Students have the potential to do this activity not only at school, but they will be interested in doing it at home as well as with their families. In this way, learning will continue to run optimally.

5. CONCLUSION

The result of this study is a STEM learning model that can be applied to elementary school STEM education which aims to (a) develop STEM knowledge, (b) improve thinking skills, and (c) improve attitudes and skills needed in carrying out tasks or jobs. Students become interested in growing, caring for and studying the vegetables they grow with the help of IoT.

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