Preservice physics teachers' laboratory project design: Arduino-based creativity

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Preservice Physics Teachers' Laboratory Project Design: Arduino-based Creativity

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Abstract. The aim of this study is report creativity of preservice physiscs teachers in design physics laboratory based on Arduino for learning STEM. Before design the project, they were involved in an introductory theoretical part, in which they were taught the basics of Arduino and its programming language, a hands-on section in four mini-projects and theoritical about sensors and data aquisition. The study used qualitative research with the narrative design. Data collection technique used is observation. Participants is 14 pre service physics teacher that consist of 5 males and 10 females in an LPTK that is located in Bandung, Indonesia. This course is part of the Sensor and Transducer subject. Implementation of the learning activity in online modes because of pandemic covid-19. Each of fifteen PPT were given an assignment to think about and design a laboratory activity in physiscs education for support learning physics where sensor and Aduino were used. The instrument that used to collect data is Creativity Product Analysis Matrix (CPAM). There are three creativity dimensions that used in this study which are resolution, elaboration and novelty dimension. With guidance instructor and amount of online resource related to Arduino, average of their design creativity of the physics laboratory in good category.

INTRODUCTION

Teaching students' knowledge and skills in Science, Technology, Engineering, and Mathematics (STEM) is believed by researchers to be an important thing to do. The researchers believed that by implementing STEM education, students can study mathematics and science and increase student interest in a career in engineering, science, and technology in the future [1] and functioned as a tool for facilitating students become STEM literate [2].

For the successful in implementation STEM in classrooms the role of teachers is crucial. In many cases, integrated within the four subjects that make STEM teaching and learning activities possible still difficult. Teachers' knowledge of meaningful use of technology for effective teaching and learning of STEM content is still low and understanding of the pedagogical approach to implementing technology-integrated courses is also lacking. These two things are obstacles that teachers face when they want to teach STEM [3]-[5]. Emerging obstacles faced by teachers show the importance of preparing science teachers with skills in applying STEM in their classrooms.

In context technology in STEM, the most widely used and developing educational technologies available today is the use of Arduino. As an open-source electronics platform based on easy-to-use hardware and software used, Arduino is used to build electronics projects. Microcontroller, basically a really small computer, is one thing in common that all of Arduino boards have. With the Arduino, we can design and build devices that can interact with our environment surroundings. The Arduino boards are able to read inputs with their onboard microcontroller (eg. Light on a sensor, an object near a sensor) and turn it into an output (Drive a motor, ring an alarm, turning on an LED, display information on an LCD). With the Arduino, makers and electricians can easily prototype their products and make their ideas come to life. The Arduino boards are now widely known and variations are well established as hobby electronics, as well as in education. Arduino has greatly contributed to technology education. There are in the literature a number of Arduino platform for academic research and educational. Based on aduino, researchers have developed educational projects

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for teach STEM in high shcool student [6] [7] and to enhance students' learning experiences in undergraduate student [8].

Technology is an important thing to be mastered by teachers in this modern era, therefore the education system must prepare teachers with the skills needed to deal with technological advances. Mastery of technology is important in an effort to increase student interest in the STEM field through the application of learning in the classroom. Therefore, teachers are expected to deepen their knowledge of technology-pedagogical-and-content (TPACK). In teacher training, Arduino-robotics have designed, implemented, and studied to create and implement STEM teaching practices for middle school science and math teachers [9], using an Arduino-based low-cost DAQ (Data Acquisition) in science teacher training for elementary school science teachers [10].

In the 21st century, students are required to have competence in problem solving, critical thinking, collaboration, communication, and creativity or innovation and Arduino is expected to be able to give students the opportunity to develop the competencies needed to become the 21st century workforce [11]. Creativity is considered an integral part of 21st century skills. Because it integrates science, mathematics, engineering, and technology, STEM is considered capable to assist students in combining science, mathematics, engineering, and technology to innovate in producing new products. Therefore, STEM education is an approach that can develop creativity [12]. The challenge of designing a particular product and product-oriented learning process from design-based learning is in line with the nature of creativity. Therefore, the STEM-Engineering design process approach can be applied as a means to foster creativity [13] and a creative product is influenced by pre-service physics teachers' STEM knowledge [14]. To assess the performance of a creativity, researchers generally use instruments such as the Guilford Battery Creativity Test, which assesses fluency, flexibility, novelty, elaboration, and sensitivity and the Torrance Test of Creative Thinking (TTCT), which is to assess the characteristics of fluency, flexibility, novelty, elaboration. , inventiveness and penetration [15]. Consensual Assessment Technique and teacher views could also be used to assess creativity [16]. Creativity Product Analysis Matrix (CPAM) developed by Besemer and Treffinger was used for investigate the effect of STEM project-based learning on students' creativity in the concept of light and optics [17].

In science education to enrich the teaching process and to verify or confirm the underlying theoretical concepts generally is supported by experiments in front of students. Traditionally in laboratory, to discover and measure phenomena student/teacher still using low technology equipment like using a stopwatch to measure time, and ruler to measure distance. The Arduino is particularly suited to measurement and control processes, utilize sensor that is controled by Arduino will result accurate measurement and what is important is to involve student in STEM learning. Considering that preparation science teacher literate in STEM should begin at pre-service level, we train pre-service teachers (PPT) in a series of activities that involving Arduino board. At the end of the training, in an effort to improve their learning experience regarding the benefits and applications of Arduino, students are given an assignment that requires them to design a physics laboratory project by applying Arduino and sensors in physics practicum tools. In this article we describe how creativity of PPT in apply the steps in design physics laboratory, involving Arduino and sensor for physics learning to helps them think creatively and can implementation in STEM leaning.

METHOD

The study used qualitative research with the narrative design. In this research designs researcher describes in the form of narratives the things that happened during class, collects and explains stories about students' lives and experience [18]. Observation is used as data collection technique where the researcher has a role as non-participant in the study. The researcher only watches and observe the activities in the class and not directly involves in the observed situation.

Fifteen PPT in 7th semester, participated in this study that consist of 5 males and 10 females taking the course of Sensor and Tranducer. The course was offered as an elective course and all of the participant have passed the subjects related to electronics. Participant have been involved on the previous course where they learned about basic of Arduino, its programming language, hands-on activities by doing some simple Arduino projects for beginners and learning theoritically about sensors and data aquisition.

This course is part of the Sensor and Transducer subject. Implementation of the learning activity in online modes because of pandemic covid-19. Each of fifteen PPT were given an assignment to think about and design a laboratory activity in physiscs education for support learning physics where sensor and Aduino were used. They were given a month in doing the task. The stages and activity in design the project was shown in Table 1.

TABLE 1. Stages and activity in design the project

Stage	Activity
Preparation	1. Instructor gave PPT freely an opportunity to choose physics lab related to physics learning in school 2. Instructor explain about design report that must covered: a) Experiment title, b) Purpose of experiment, c) Theory, d) Apparatus, e) Scheme of apparatus, f) Principle of apparatus work, g) Data table from observation. 3. Class discussion in determining topic lab distribution for ech PPT
Implementation	1. PPT find some information that needed to design physics lab project based on Arduino from internet 2. PPT produce the design 3. PPT report they design in a written report form.
Revision	1. Instructor gives an evaluation regarding design physics lab project 2. Students make revisions of the design according to suggestions and feedback from the instructor
Communication	1. Student communicate their design in front of the instructor dan another students. 2. Instructor and another students comment and gave suggestion for enhance

Research instrument that used to collect data is creativity product analysis matrix (CPAM) that was developed by Besemer and Treffinger (1981). The data that was collected from students' creativity is based on design project report. For each creativity criterion, the resulting design is rated on a scale of 1 to 3. The criterion that used is valuable, useful, well-crafted, expressive, original and novelty. The creativity product analysis matrix (CPAM) can be shown in Table 2.

TABLE 2. Instrument for creative product analysis matrix (CPAM)

Creative Dimension	Criterion	Score 1	Score 2	Score 3
Novelty	Geminal	The product is inspiring others with the creation	The product is inspiring others to try something new	The product is inspiring others to try something new by directly give ideas to develop more product design
	Original	Student use the previous finding as their product idea	Students use the previous finding as their idea, but they make a modification of the product	The product idea comes from their own understanding
Resolution	Valuable	The product is not compatible with the purpose and not relates to the concept	The product is compatible with the purpose and not relates to the concept	The product is compatible with the purpose and relates to the concept
	Usefull	The product can be used once	The product can be used continuously with a certain requirement	The product can be used continuously without any requirement
Elaboration	Well Crafted	The product is done well	The product is done well with the good looking design	Students take an effort to give interesting product design by using some materials
	Expressive	The product is presented with lacking body language and need to control speaking tone, not understandable	The product is presented with lacking body language and need control speaking tone, but understandable	The product is presented in a communicative way (using effective body language and clear voice) and understandable manner

RESULT AND DISCUSSION

This article reports on the creativity of PPT in designing a physics laboratory using Arduino. The aim is for PPTs to have knowledge of meaningful use of technology in effective learning of STEM content and they have a pedagogical approach when they want to implement technology-integrated courses as part of STEM education. PPT take on the activity enthusiably with only one student drop-out. In the first periode, before designing the project, at first PPT were trained on the acquisition of Arduino board material. In the second, they were given explanation the basics of the Arduino programming language. This programming language is a simple level which PPT only needed to understand the variables, functions, and structures the code of an example mini project. The approach is learning-by-doing where student build simple Arduino projects for beginners in order to exercises to master Arduino basics. In the second periode. students learned about sensor and data aquisition theories. With knowledge about the acquisition of Arduino board material and its programming language, practice in building simple Arduino projects and knowledge about sensor and data acquisition theories they are challenged to design a laboratoy physics education using two different kinds of sensor. Name of student, title of project design and type of sensors used can be seen at Table 3.

TABLE 3. Name of student, title of project design and type of sensors

Name	Project Design Title	Sensors Type
AK	Pascal Law Apparatus Using Load Cell Sensor as Digital Balance Based on Arduino	Load Cell
MRS	Developing Newton Second Law Lab Apparatus Using Ultrasound and Infra red Sensor	Ultrasound And IR
SNZ	Physics Lab Apparatus for Measure Freely Falling Objects Based on Arduino	Ultrasound
WS	Lab Apparatus for Motion at Constant Acceleration Using Ultrasound Sensor	Ultrasound
AI	Physics Lab Apparatus for Learning Fluids using Water Flow Yf-S201 Sensor Based on Arduino	Effect Hall
AF	Physics Lab Apparatus for Determining Gravitation Using Hc-Sr04 Sensor	Ultrasound
DM	Physics Lab Apparatus for Learning Spring Oscillation Using Hc-Sr04 Sensor	Ultrasound
EM	Distance Measuring Using 4 Ultrasound Sensors	Ultrasound
KA	Physics Lab Apparatus for Learning Simple Harmonic Oscilator Based on Arduino	Ultrasound
KH	Digital Thermometer Based on Arduino	IR
MRH	Temperature and Humidity Room Instrument Based on Arduino Uno R3 with DHT11 Sensor	Temperature and Humidity
MFR	Tachometer as Instrument Angular Velocity	IR and Ultrasound
QMA	Instrument Light Intensity Using LDR Arduino-Based	Light
RA	Determining Joule Constant Using Digital Based on Temperature Sensor LM 35	Temperature

There were four from fifteen design report have complied with the establised rules in writing repot. Eleven PPT were asked to revised their design and they were given a week to complete. They had to revise: 1) Structure of report, 2) Scheme of apparatus, 3) Principle of apparatus work, 4) Data table from observation. In the end of activity they had to present their report by online where instructor and other sudents gave suggestion and feedback.

The analysis of the data were obtained from the CPAM instrument that adapted from Besemer and Treffinger (1981). Specifically there were three creative dimension based on CPAM namely resolution, elaboration, and novelty. The data is obtained based on the criterion of each creativity dimension. Each criterion is scored with a rubric scale from 1 until 3 based on several requirements. Average score for every aspect creativity for 14 students was shown in Table 4.

TABLE 4. Students' creativity result

Creative Dimension	Criterion	Average Score
Novelty	Germinal	81
	Original	81
Resolution	Valuable	79
	Usefull	81
Elaboration	Well Crafted	76
	Expressive	88

Expressive has the highest frequency in students' creativity. Preservice physics students were able to provide detailed explanations for their design. Well crafted has the lowest frequency. In this aspect, 76 % students' design have done well with the good looking. Figure 1 show PPT's design of the Pascal Law Apparatus.

The average score for each dimension of creativity is 81% which is categorized as good [16]. Based on the findings of this study, the highest frequency was obtained at novelty followed by resolution and elaboration. Based on the results of this study, PPT has good creativity. The results obtained, allegedly because during the training they were guided to realize their ideas and their designs through clear stages. The training that was carried out before the PPT was assigned to design a practicum tool, namely through learning by imitating (learning and practicing several different sensors) in the previous course was an indicator that it was not a difficult activity for PPT when they had to integrating sensors with Arduino boards [19]. The ease of use of this sensor and Arduino is able to empower PPT to do creative designs.

The results showed that creative design that was categorized as good was the result of teaching through stages that starting from the introduction of Adunino technology and the programming environment as well as learning related to sensors and transducers. Moreover, it is undeniable that the resulting creativity were influenced by several reasons including the exposure to some ideas that came from youtube, amount of online resource related to Arduino. Arduino users community and their supporting materials can be found trough the internet so as to make it easier for users and hobbyists to find information and examples about Arduino [19].

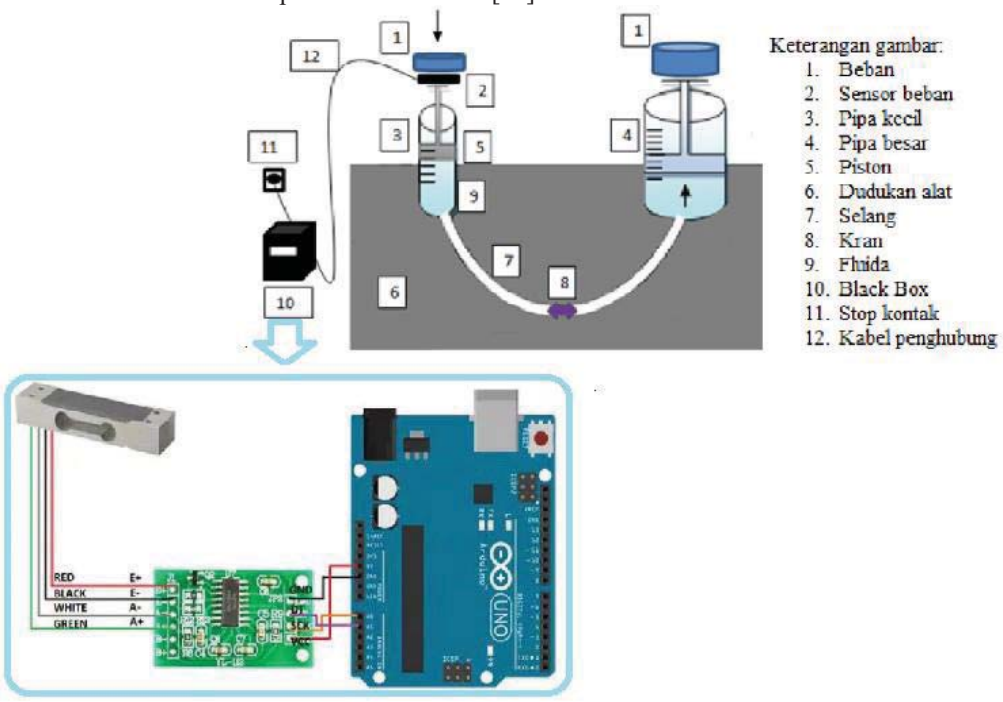

FIGURE 1. Preservice physics teacher's design of the pascal law apparatus

CONCLUSION

Pre sevice physics teacher have good creativity in the dimension of resolution, elaboration, and novelty. In addition to guidance from the instructor, the creativity of their ideas is influenced by the availability of information sources on the internet and from Youtube related to Arduino. Pre sevice physics teacher interested in implement thes design and they do not mind to buy a set of Arduino to do projects at home if Arduino kit is given freely. The creativity of PPT in designing practicum tools is expected to be able to transfer their course experience on technology integration into their own teaching by including technology as an educational tool in the secondary school STEM curriculum and can contribute to improving student learning and fostering student interest in technology and engineering.

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