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STEM Teaching Materials Integrated with Arduino Science Journal for Biology Prospective Teachers

Nawawi[1*], Ivan Eldes Dafrita[2*]

Biology Education Study Program, IKIP PGRI Pontianak, Ampera Street no.88, Pontianak City, Indonesia

[1]nawawi@ikippgriptk.ac.id*; [2]ivaneldesdafrita@ikippgriptk.ac.id*
*corresponding author

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Abstract

One effort made by the Biology Education Study Program to provide 21st-century skills to prospective biology teacher-students is to teach STEM through STEM courses. This research covers the issue of developing innovative learning-based teaching materials and developing 21st-century competencies. The research design used in product development was referred to the Thiagarajan 4D development model, such as the define, design, develop, and disseminate stage. The research objective is to understand STEM learning materials based on Arduino Science Journal in improving prospective 21st-century biology teachers. In particular, to determine: (1) The level of validity of Arduino Science Journal-based STEM teaching materials in increasing 21st-century biology teacher candidates. (2) The levels of the practicality of STEM teaching materials based on the Arduino Science Journal to improve prospective 21st-century biology teachers. (3) The Effectiveness of Arduino Science Journal-Based STEM Teaching Materials in Improving the Learning Outcomes of Prospective 21st Century Biology Teachers. The data of research is the percentage value of the validity and practicality. The results of this study indicated that the Arduino Science Journal integrated STEM teaching materials developed, had satisfied the criteria of validity and practicality, and were used effectively in STEM learning.

1. INTRODUCTION

After the announcement of the first confirmed positive case in Indonesia by the Ministry of Health in April 2020, the Indonesian government has established a Covid-19 task force in Indonesia to tackle the spread of the virus. A massive restriction policy is then regulated in the *Permenkes* number 9 of 2020. The policy include the restriction on the movement of citizens, transportation, public transportation, private vehicles, schools, workplaces, restrictions on religious activities, social conditions, and cultural activities leading to mass gatherings (Irawan et al., 2020). In accordance with that, the Ministry of Education and Culture has issued circular letter No. 15 of 2020 concerning Guidelines for the Implementation of Learning from Home (BDR) in the emergency period of the spread of the Covid-19 pandemic virus. The policies taken by the Ministry of Education and Culture of the Republic of Indonesia due to the Covid-19 pandemic

have affected all levels of the national education system, from Kindergarten to Higher Education (Oyedotun, 2020).

IKIP PGRI Pontianak is an Educational Institution and Education Personnel that produces quality output and graduates professional education personnel in education, especially in the West Kalimantan Region. IKIP PGRI Pontianak has an essential role in creating academic staff who have the skills and abilities needed during the Covid-19 pandemic. From the learning process that IKIP PGRI Pontianak has carried out, not only transfer of knowledge but students are invited to understand the nature of concepts and materials provided through meaningful learning that prospective student teachers can develop through independent learning through face-to-face meetings and face-to-face virtual meetings through various learning modules, online learning applications, and online and offline practical activities.

Changes and demands to create competent, professional, and competitive graduates in the era of the industrial revolution 4.0 are challenges for IKIP PGRI Pontianak in the current pandemic. The Biology Education Study Program seeks to prepare and equip prospective Biology teacher students with the four basic skills (4C) needed to adapt to change. The changes and challenges that occur require lecturers to be more creative, innovative, and can develop various teaching materials, learning media, practicum modules, and textbooks following the development of the digital world. There are four skills needed by prospective 21st-century biology teacher students: (1) Critical Thinking and Problem Solving, namely the ability to think critically and solve problems. (2) Creativity and innovation, namely the ability to be creative and innovate. (3) Communication, namely the ability to communicate. (4) Collaboration, namely the ability to work with other people. Meanwhile (Makaramani, 2015), people need to know how to use their knowledge and skills by thinking critically, applying knowledge to new situations, and analyzing the information obtained to success in the 21st-century era. This opinion is in accordance with the increasing demand for labor needs with STEM skills, and competencies will affect STEM teaching and education patterns from basic levels such as in schools to higher education (Cheng et al., 2020).

One effort made by the Biology Education Study Program to provide 21st-century skills to prospective biology teacher-students is to teach STEM through STEM courses. STEM applied in lectures will encourage students to design, utilize, develop technology, hone cognitive abilities, hone manipulative skills that can be applied in accordance with the knowledge gained (Permanasari, 2016). Science, Technology, Engineering, and Mathematics have been adopted and developed in developed countries such as the United States (US), Singapore, Australia, and even Finland. Indonesia has integrated STEM into the 2013 Curriculum. Aligns with (Agustina, 2017), the STEM approach can be applied from the elementary school to to post-doctoral levels.

Various studies related to the application and integration of STEM in learning have been carried out, such as the application of Project-Based Learning by integrating STEM in education can affect scientific literacy, and increase the motivation and learning interest of SMPIT students in Sukabumi Regency (Afriana et al., 2016). Similar research, such as applying STEM Project-Based Learning in the learning process, can improve creative thinking skills (Ismayani, 2016). Meanwhile, STEM integrated into the reproductive system of plants and animals, significantly affects students' scientific thinking skills (R. Agustina et al., 2020). It shows that STEM needs to be taught to prospective biology teachers as a teaching tool.

The use of printed teaching materials in STEM lecture learning modules can help develop 21st century learning for prospective biology teacher students. The characteristics of the module according to (Selviani, 2019), are: (1) there is learning that can be conducted independently by students; (2) contains the formulation of specific and explicit learning objectives; (3) there is an orderly sequence of knowledge; (4) can provide direct reinforcement to students; (5) equipped with an evaluation. In accordance with research conducted by (Oktavia, 2019), the use of STEM teaching materials in lectures can improve learning outcomes, critical thinking skills, and students' creative thinking skills. The teaching materials developed by the researchers align with the directions and objectives of the Institute for Research and Community Service (LPPM), namely the development of innovative learning-based teaching materials and the development of 21st-century competencies for IKIP PGRI Pontianak students.

Based on the results of online learning observations at the Biology Education Study Program during the Covid-19 pandemic. Students can adapt to online learning, and use Android phones to submit online assignments, make online presentations, and work on online questions. However, it is still necessary to optimize the use of android mobile devices for STEM lecture activities during the Covid-19 pandemic.

Based on the results of previous studies, many studies only focused on module development. In addition, the lack of research conducted using the Arduino Science Journal in Indonesia in lectures. Therefore, in this study, the Arduino Science Journal application is integrated with the developed STEM module. Meanwhile, student learning as teacher candidates can use the Arduino Science Journal Application for learning in their teaching practice at school later.

This research covers two issues: the issue of developing innovative learning-based teaching materials and developing 21st-century competencies in the research strategy of IKIP PGRI Pontianak on fundamental studies and the development of innovative learning teaching materials in 21st-century competency studies. The research developed STEM teaching materials by integrating the Arduino Science Journal to improve the 21st-century skills of a prospective biology teacher. Students are expected to be a reference for lecturers in developing innovative teaching materials by integrating technology or applications available on the play store to be used in learning to improve the 21st-century competence of prospective biology teacher students at IKIP PGRI Pontianak. This research is also in accordance with the vision of IKIP PGRI Pontianak and the vision of the Biology Education study program, in which one of the visions is to create superior graduates. These graduates who excel in mastering learning support technology in the era of the industrial revolution 4.0. and industrial revolution 5.0.

The research objective is to understand STEM learning materials based on Arduino Science Journal to improve prospective 21st-century biology teachers. In particular, to determine: (1) The level of validity of Arduino Science Journal-based STEM teaching materials in increasing 21st-century biology teacher candidates. (2) The level of practicality of STEM teaching materials based on the Arduino Science Journal in improving prospective 21st-century biology teachers. (3) The Effectiveness of Arduino Science Journal-Based STEM Teaching Materials in Improving the Learning Outcomes of Prospective 21st Century Biology Teachers.

2. METHOD

This research is a research and development (Research and Development) to produce a new product (STEM Teaching Materials) that can be used by prospective teacher students in the Biology Education Study Program, IKIP PGRI Pontianak. The research design used in product development was referred to the Thiagarajan 4D development model, where there are four stages in the Thiagarajan 4D development model: define, design, develop, and disseminate Thiagarajan in (Hidayati et al., 2019). Figure 1. describes the method of the 4D development model STEM teaching materials integrated with Arduino Science Journal to improve 21st-century skills of biology prospective teachers.

Two media and material experts carried out validation. At the same time, the product trial subjects in this development research were students of the Biology Education Study Program, IKIP PGRI Pontianak, who took STEM courses at the Biology Education Study Program. The results of the validation by experts were then analyzed with the following formula:

$$Rating\ results = \frac{\sum validator's\ answer}{\sum highest\ score} \times 100\% \quad \text{(Lestari, 2018)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The level of validity measured by calculating the Likert scale is presented in Table 1.

Table 1. Product Validity Level

Evaluation	Value Scale	Rating Results Persentage (%)
Very Valid	5	86% - 100%
Valid	4	66% - 85%
Quite Valid	3	51% - 65%
Invalid	2	36% - 50%
Very Invalid	1	20% - 35%

Riduwan in (Hidayat et al., 2020)

The practicality assessment was obtained from the results of the practicality assessment by material and media experts with the percentage technique using the formula:

$$Percentage = \frac{\sum Total\ Score}{\sum Ideal\ Maximum\ Score} \times 100\% \quad \text{(Tegeh, 2020)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The level of practicality measured by calculating the Likert scale shown in the following table;

Table 2. Product Practicality Level

Evaluation	Scale Value	Percentage (%)	Description
Very practical	5	86-100	No Requirement Revision
Practical	4	66-85	No Requirement Revision
Practical Enough	3	51-65	Revision Requires Slight
Not Practical	2	36-50	Revision
Very impratical	1	20-35	Not Worth Using

source adapted from (Haqqi & Yafie, 2019)

While the effectiveness test used a one-group pretest-posttest design with an accuracy was obtained by comparing before and after using STEM teaching materials integrated with Arduino Science Journal. In the field trial, data were collected using pretest and posttest to determine the difference in the 21st-century skills of experimental group students before and after using development products in the form of STEM teaching materials based on Arduino Science Journal. The data analysis technique used a paired-samples t-test with SPSS.

3. RESULTS AND DISCUSSION

The Arduino Science Journal-based STEM teaching materials developed have followed the 4D Thiagarajan development stages. There are four stages in the Thiagarajan 4D development model, namely, define, design, develop and disseminate Thiagarajan in (Prayitno, 2017). The steps for developing Arduino-based STEM teaching materials can see in Figure 1.

Figure 1. Thiagarajan 4D development model (Prayitno, 2017)

In the define stage, five activities were carried out, namely; 1) Analysis of initial conditions; at this stage, the researcher identified and determined the fundamental problems faced in the learning process of STEM courses in the Biology Education Study Program. The results of the initial condition analysis were used in determining the initial requirements. The initial conditions for selecting the correct sequence were used to compile materials in developing STEM-based teaching materials with the Arduino Science Journal. 2) Student analysis was carried out to identify student characters as target users of STEM teaching materials based on the Arduino Science Journal. We analyzed descriptively by gathering information from colleagues who had taught in previous courses. The information obtained was in the form of student learning motivation, soft and hard skills that had been mastered, and 21st-century skills that had been mastered as initial capital in STEM learning. 3) Analysis of the concept of STEM teaching materials based on Arduino Science Journal, by making lesson plans, descriptions, and objectives of STEM courses. We analyzed the STEM concept taught to Biology Education study program students by integrating the Arduino Science Journal application, which could be downloaded on the Playstore and installed on student devices. 4) Task analysis, to achieve the competencies following the learning objectives in STEM courses. 5) Analysis of 21st century skills, to integrate 21st century skills to prospective biology teacher students so that students expect to have 21st century skills that they could use in school practice.

The second stage in the development of 4D Thiagaradjan designs had four activities, namely; 1) Exam preparation is the most critical part in measuring students' abilities after carrying out activities using STEM teaching materials based on Arduino Science Journal. Tests were given at the end of each chapter in the teaching materials to measure the achievement of student competencies. 2) Media Selection, we determined the Arduino Science Journal application as an integrated media used by students at this stage. The selection of the Arduino Science Journal followed the results of concept analysis, media analysis, and the characteristics of students who used STEM teaching materials, including the calculation of 21st-century

skills to be taught. 3) The selection of formats in developing STEM teaching materials based on the Arduino Science Journal was adjusted to the pandemic conditions in the 2020/2021 academic year, with the implementation of learning carried out alternately online and offline. 4) the initial design stage was obtained as the initial draft of STEM teaching materials based on the Arduino Science Journal, which still required testing and review from media experts and material experts.

The third stage is develop. At this stage, the Arduino Science Journal-based STEM teaching materials were ready to be validated by material and media experts. The material and media experts involved two people. The review results can see in table 3 and table 4.

Table 3. Material Expert Validation Results on STEM Teaching Materials

No	Rated aspect	Material Expert Score		Average Percentage Validity	Validity Criteria
		1st	2nd		
ELIGIBILITY OF CONTENTS					
1	The suitability of the material with KI and KD	100.00%	93.33%	96.67%	Very valid
2	Material Accuracy	86.67%	90.00%	88.33%	Very valid
3	Supporting Study Material	100.00%	100.00%	100.00%	Very valid
SERVICE ELIGIBILITY					
1	Presentation Techniques	80.00%	80.00%	80.00%	Very valid
2	Presentation Support	80.00%	90.00%	85.00%	Very valid
LANGUAGE					
1	Easy	80.00%	90.00%	85.00%	Very valid
2	Communicative	80.00%	100.00%	90.00%	Very valid
3	Dialogue and Interactive	80.00%	100.00%	90.00%	Very valid
4	Confusion	80.00%	100.00%	90.00%	Very valid

Table 4. Media Expert Validation Results on STEM Teaching Materials

No	Assessment Aspect	Score Media Expert		Average Percentage Validity	Validity Criteria
		1st	2nd		
1	Module Size	80.00%	80.00%	80.00%	Very valid
2	Cover design	92.50%	80.00%	86.25%	Very valid
3	Module Content Design	83.53%	87.06%	85.29%	Very valid

Table 5. Percentage of Practicality of Material Experts on STEM Teaching Materials

No	Rated aspect	Material Expert Score		Average Percentage Validity	Practicality Criteria
		1st	2nd		
	ELIGIBILITY OF CONTENTS				
1	The suitability of the material with KI and KD	100.00%	93.33%	96.67%	Very practical
2	Material Accuracy	86.67%	90.00%	88.33%	Very practical
3	Supporting Study Material	100.00%	100.00%	100.00%	Very practical
SERVICE ELIGIBILITY					
1	Presentation Techniques	80.00%	80.00%	80.00%	Practical
2	Presentation Support	80.00%	90.00%	85.00%	Practical
LANGUAGE					
1	Easy	80.00%	90.00%	85.00%	Practical
2	Communicative	80.00%	100.00%	90.00%	Very practical
3	Dialogue and Interactive	80.00%	100.00%	90.00%	Very practical
4	Confusion	80.00%	100.00%	90.00%	Very practical

Table 6. Percentage of Practicality of Media Experts on STEM Teaching Materials

No	Assessment Aspect	Score Media Expert		Average Percentage Validity	Practicality Criteria
		1st	2nd		
1	Module Size	80.00%	80.00%	80.00%	Practical
2	Cover design	92.50%	80.00%	86.25%	Very practical
3	Module Content Design	83.53%	87.06%	85.29%	Very practical

Table 7. Results of Data Normality Test

	Class	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
N gains_ Percentage	Learning using STEM Teaching Materials	.105	40	.200*

Based on the results of the Normality Test using the Kolmogorov Smirnov test using SPSS 25, the results of Sig. 0.200 > 0.05. It can be concluded that the data were normally distributed. As the data were normally distributed, it was continued with the paired sample t-test.

Table 8. Results of Paired Sample t-Test

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre - Post	-20.375	14.605	2.309	-25.046	-15.704	-8.823	39	.000

Based on the Paired Sample t-Test test data obtained Sig (2-tailed) 0.000 <0.05, the information was accepted that there was a significant difference in the learning outcomes of pre-test and post-test data. It can be concluded that the use of STEM learning materials based on Arduino Science Journal could improve the Learning Outcomes of Prospective 21st Century Biology Teachers.

Based on the results, STEM teaching materials based on Arduino science journals followed the development model. The series of development activities carried out to produce teaching materials for prospective biology teacher students can be applied when teaching in schools. The development phase started with an analysis of the needs for developing STEM teaching materials based on the Arduino Science Journal, an analysis of the curriculum and student needs, and the selection of formats and expert validation and testing of students. Meanwhile, according to (Haqqi & Yafie, 2019), expert assessments at the development research stage are essential because the results are converted using assessment criteria to determine whether or not a revision of the product design has been developed. This opinion is in accordance with (Nurhasanah et al., 2020) that in terms of the ease of use of the module, both teacher and student responses produce a chemical equilibrium module with a very high level of validity and practicality.

The improvements made were obtained at the development stage to get a valid and practical module where the results of the material expert assessment showed that the module was categorized as very good and very practical in terms of Content Feasibility, Service Eligibility, Language. Meanwhile, the material expert's assessment results were excellent and very practical in terms of Module Size, Cover Design, and Module Content Design. Meanwhile, the pilot phase involved 40 students from biology study programs who took STEM courses. The final stage of this development research is Disseminate. Researchers have submitted and published ISBN 978-623-360-067-5 with JSI Publisher at this dissemination stage. The

published module is integrated with the Arduino Science Journal application, downloaded via the Play store. Meanwhile (Van Nuland et al., 2020), e-learning tools allow students to conceptualize structures that cannot be seen with the naked eye, such as atoms or cellular structures and visualize complex processes such as protein synthesis.

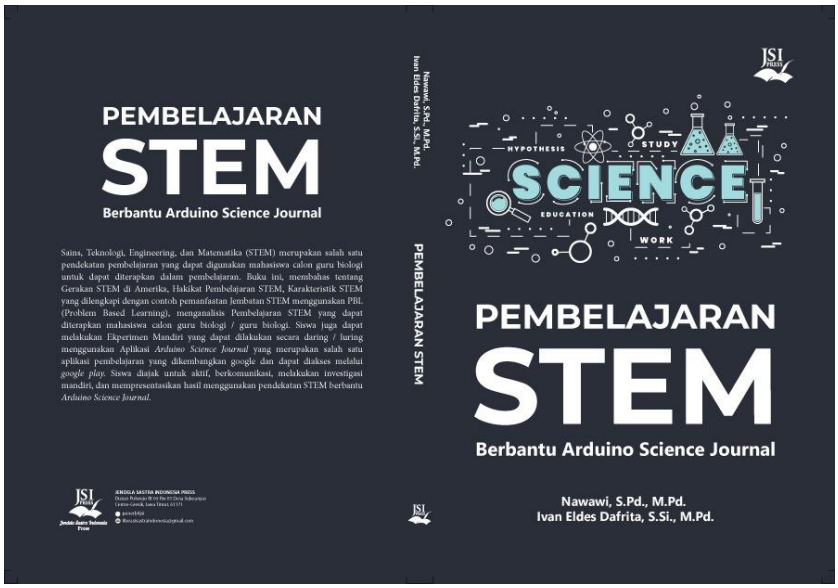

Figure2. Book Cover Image from publisher

The steps carried out are similar to those (Lestari, 2018), which state that after developing the Biotechnology LKM with the PBL model, it is declared valid and practical. Trials could be conducted using N-gain calculations to measure the effectiveness of MFIs with the PBL model. Meanwhile, according to the view (Prayitno, 2017), the teaching materials developed must fulfil the principles of consistency, adequacy, and the relationship between competency standards and essential competencies. Thus, in the development of teaching materials, modules and LKM must be carried out to measure the validity and practicality of the developed teaching materials. STEM learning can change student skills and activate students in learning so that learning looks more fun (Dewati et al., 2019). Meanwhile (Segarra et al., 2018), STEM learning can increase mastery of scientific concepts, build underserved technical skills in the curriculum, and increase students' mastery of cross-scientific design and collaboration.

4. CONCLUSION

Based on the development results, it was found that STEM teaching materials integrated with the Arduino science journal fulfil the very valid and practical criteria of material and media experts and were effective for students to use in learning STEM subjects.

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