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# STEM TEACHING MATERIALS INTEGRATED WITH ARDUINO SCIENCE JOURNAL FOR BIOLOGY PROSPECTIVE TEACHERS

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Article history	Abstract
Submission :	One of the efforts 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 refers to the Thiagarajan 4D development model, such as define, design, develop, and disseminate stage. The research objective is to find out STEM learning materials based on Arduino Science Journal in improving prospective 21st-century biology teachers. In particular, to find out: (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. The data of research is the percentage value of the validity and Practicality. The results of this study indicate that the Arduino Science Journal integrated STEM teaching materials developed have met the criteria of validity and practicality and are effective for use in STEM learning.
Revised :	
Accepted :	
<b>Keyword</b>	
STEM	
Teaching Materials	
Arduino Science Journal	



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## 1. INTRODUCTION

After the announcement of the first confirmed positive case in Indonesia by the Ministry of Health in April 2020, the Indonesian government established a Covid-19 task force in Indonesia to tackle the spread of the virus. A policy of massive restrictions then regulated in Permenkes number 9 of 2020. The policy of limiting 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 line with that, the Ministry of Education and Culture 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 global education system, from Kindergarten to Higher Education (Oyedotun, 2020).

<sup>1</sup> <https://jurnal.unimus.ac.id/index.php/JPKIMIA/index>



IKIP PGRI Pontianak as an Educational Institution and Education Personnel that produces quality output and graduates of 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. From the learning process that IKIP PGRI Pontianak has carried out. Not only transfer of knowledge but students invited to understand the nature of concepts and materials provided through meaningful learning that prospective student teachers can develop through independent learning either through face-to-face meetings, as well as 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 industrial revolution 4.0 challenge 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 the changes. The changes and challenges that occur require lecturers to be more creative, innovative, and able to develop various teaching materials, learning media, practicum modules, and textbooks following the digital world's development. In general, there are four skills needed by prospective biology teacher students in the 21st century, including: (1) Critical Thinking and Problem Solving, namely the ability to think critically and solve problems. (2) Creativity and innovation, namely the ability to creativity and innovation. (3) Communication, namely the ability to communicate. (4) Collaboration, namely the ability to work with people other.

One of the efforts 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 following 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 itself has integrated STEM into the 2013 Curriculum. Aligns with (G. Agustina, 2017), the STEM approach can be carried out starting at the elementary, junior high, high school, and 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, increase motivation and learning interest of SMPIT students in Sukabumi Regency (Afriana et al., 2016). Similar research such as applying STEM Project-Based Learning in learning can improve creative thinking skills (Ismayani, 2016). While STEM, which has integrated into the reproductive system of plants and animals, significantly influences students' scientific thinking skills (R. Agustina et al., 2020). Meanwhile, it shows that STEM needs to teach 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), namely: (1) There is learning that can be done 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 evaluation. In line with research conducted (Oktavia, 2019), using 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. IKIP PGRI Pontianak students.

Based on the results of online learning observations at the Biology Education Study Program during the Covid-19 pandemic. Students were able to adapt to online learning, and students were able to use Android phones to collect online assignments, make online presentations, and do 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 research, so much research only focused on module development, but what is new in this research is the use of the Arduino Science Journal application 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. As well as the lack of research conducted using the Arduino Science Journal in Indonesia in lectures.

This research covers two problems: the issue of developing innovative learning-based teaching materials and developing 21st-century competencies in the research strategy of IKIP PGRI Pontianak on



the topic of basic studies and the development of innovative learning teaching materials in 21st-century competency studies. The research was conducted on the development of 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 line with the vision of IKIP PGRI Pontianak and the vision of the Biology Education study program, where one of the visions is to create superior graduates. These namely graduates excel in mastering learning support technology in the era of the industrial revolution 4.0. and the era of the industrial revolution 5.0.

The research objective is to find out STEM learning materials based on Arduino Science Journal in improving prospective 21st-century biology teachers. In particular, to find out: (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 refers 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 3.1 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 validation by experts were then analyzed with the following formula;

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

The level of validity is measure by calculating the Likert scale shown in the following table;

**Table 1.** Product Validity Level

Evaluation	Value Scale	Rating Results Percentage (%)
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 is obtained from the results of the practicality assessment by material and media experts with the percentage technique using the formula;

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

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

**Tabel 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 impractical	1	20-35	Not Worth Using

While the effectiveness test uses a one-group pretest-posttest design, accuracy is obtained by comparing the 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 that have developed have followed the 4D Thiagarajan development stages, where 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, the researcher carried out five activities, namely; 1) Analysis of initial conditions; at this stage, the researcher identifies and determines the fundamental problems faced in the learning process of STEM courses in the Biology Education Study Program. The results of the initial condition analysis will then be used in determining the initial requirements. The initial conditions for selecting the correct sequence are 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. Our researcher analyzed descriptively by gathering information from colleagues who had taught in previous courses. The information obtained is in the form of student learning motivation, soft and hard skills that have been mastered, and 21st-century skills that have been mastered as initial capital in STEM learning. 3) Analysis of the concept of STEM teaching materials based on Arduino Science Journal, conducted by researchers by making lesson plans, descriptions, and objectives of STEM courses. The researcher analyzes the STEM concept taught to Biology Education study program students by integrating the Arduino Science Journal application, which can be downloaded on the Playstore and installed on student devices. 4) Task analysis, carried out by researchers to achieve the competencies following the learning objectives in STEM courses. 5) Analysis of 21st-century skills, conducted by researchers to integrate 21st-century skills to prospective biology teacher students so that students expect to have 21st-century skills that they can use in school practice.

The second stage in the development of 4D Thiagaradjan designs has 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 are given at the end of each chapter in the teaching materials to measure the achievement of student competencies. 2) Media Selection, the researcher determines the Arduino Science Journal application as an integrated media used by students at this stage. The selection of the Arduino Science Journal follows the results of concept analysis, media analysis, and the characteristics of students who use 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 is 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 obtained an initial draft of STEM teaching materials based on the Arduino Science Journal, which still requires 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 are ready to be validated by material experts and media experts. As for the material experts and media experts involved as many as 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 Score	Expert	Average Percentage Validity	Validity Criteria
		1st	2nd		
ELIGIBILITY OF CONTENTS					
I	The suitability of the material with KI and KD	100,00%	93,33%	96,67%	Very valid
II	Material Accuracy	86,67%	90,00%	88,33%	Very valid
III	Supporting Study Material	100,00%	100,00%	100,00%	Very valid
SERVICE ELIGIBILITY					
IV	Presentation Techniques	80,00%	80,00%	80,00%	Very valid
V	Presentation Support	80,00%	90,00%	85,00%	Very valid
LANGUAGE					
VI	Easy	80,00%	90,00%	85,00%	Very valid
VIII	Communicative	80,00%	100,00%	90,00%	Very valid
VIII	Dialogue and Interactive	80,00%	100,00%	90,00%	Very valid
X	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 Score	Expert	Average Percentage Validity	Practicality Criteria
		1st	2nd		
ELIGIBILITY OF CONTENTS					
I	The suitability of the material with KI and KD	100,00%	93,33%	96,67%	Very practical
II	Material Accuracy	86,67%	90,00%	88,33%	Very practical
III	Supporting Study Material	100,00%	100,00%	100,00%	Very practical
SERVICE ELIGIBILITY					
IV	Presentation Techniques	80,00%	80,00%	80,00%	Practical
V	Presentation Support	80,00%	90,00%	85,00%	Practical

LANGUAGE					
VI	Easy	80,00%	90,00%	85,00%	Practical
VIII	Communicative	80,00%	100,00%	90,00%	Very practical
VIII	Dialogue and Interactive	80,00%	100,00%	90,00%	Very practical
X	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 <sup>a</sup>		
		Statistic	df	Sig.
Ngains_ Percentage	Learning using STEM Teaching Materials	.105	40	.200 <sup>*</sup>

Based on the results of the Normality Test using Kolmogorov Smirnov on SPSS 25, the results of Sig. 0.200 > 0.05, concluded that the data were normally distributed. Because 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									
Pair		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
					Lower	Upper			
1	Pre - Post	-20.375	14.605	2.309	-25.046	-15.704	-8.823	39	.000

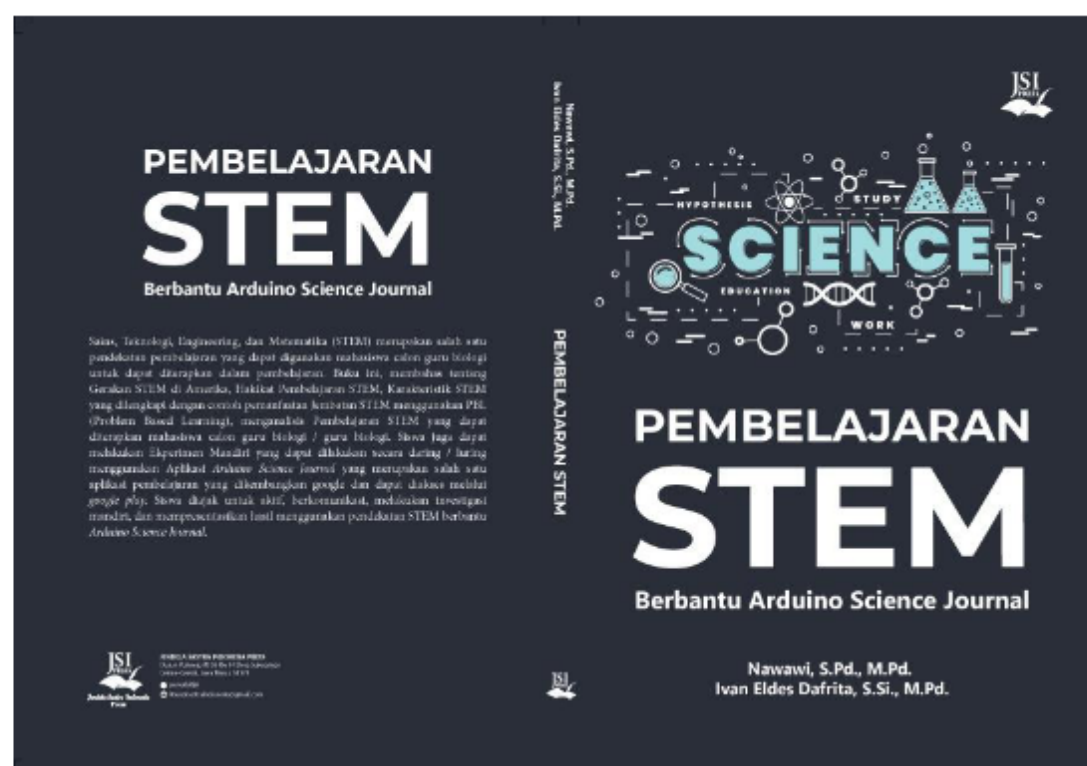
Based on the Paired Sample t-Test test data obtained Sig (2-tailed) 0.000 < 0.05, information is accepted that there is a significant difference in the learning outcomes of pre-test and post-test data. So its concluded that the use of STEM learning materials based on Arduino Science Journal could improve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

Based on the development results, STEM teaching materials based on Arduino science journals follow the developed development model. The series of development activities carried out by researchers to produce teaching materials for prospective biology teacher students can be applied when teaching in schools. The development stage starts 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 election of formats and expert validation and testing to students.

Improvements made by researchers were obtained at the development stage to get a valid and practical module where the results of the material expert assessment show that the module categorized as very good and very practical in terms of Feasibility Content, Feasibility of Service, Language. At the same time, the material expert's assessment results are excellent and very practical in Module Size, Cover Design, and Module Content Design. At the same time, the trial phase involved 40 students from the biology study program who took STEM courses. The final stage of this development research is Disseminate. In this dissemination stage, the researcher has submitted and publish the ISBN: 978-623-360-067-5 with JSI Publisher.



**Figure2.** Book Cover Image from publisher

The research steps carried out are similar to (Lestari, 2018) which states that after the modul Biotechnology with the PBL model has been developed, it is declared valid and practical. The researcher can conduct trials using N-gain calculations to measure the effectiveness of the MFI with the PBL model. Meanwhile, according to the view (Prayitno, 2017), the teaching materials developed must meet the principle of consistency, adequacy, and the relationship between competency standards and essential competencies. So in the development of teaching material, modules and LKM must be carried out to measure the validity and practicality of the developed teaching materials.

#### 4. CONCLUSION

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

#### ACKNOWLEDGMENT

The researcher would like to thank the research and community service institute (LPPM) IKIP PGRI Pontianak for research support and funding, and JPS UNIMUS for publishing research results.

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## Biographies Of Authors (11 Pt)

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