IMPLEMENTING STEM PROJECT-BASED ONLINE SCIENCE LEARNING FOR PRE-SERVICE TEACHERS

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Abstract: This research is to analyze the interests, knowledge mastered and the application of 21st century skills in online STEM learning. This research is an action in implementing project-based learning with a STEM approach which is carried out with a Learning Management System (LMS), namely Schoology and assisted by other applications, namely Zoom Meeting and WhatsApp. The participants are pre-service chemistry teachers in the second year who are taking Integrated Science courses at the Muhammadiyah University of Semarang, Indonesia as many as 16 students. The research method used a qualitative approach to find out phenomena that arise and reveal from time to time. The data obtained in the form of answers to questionnaires, pictures of STEM project diagrams, STEM product videos and STEM product descriptions. It was found that the stage changes in online STEM learning were different when it was implemented in the offline condition. It was shown that the pre-service teachers were interested in working on STEM projects, increasing their knowledge and collaboration skills. The novelty of this study is the implementation of online STEM learning in the pandemic era by involving family members.

Key words: STEM, Online Science Learning, Project-Based learning, Pre-service Teachers

A. Introduction

The acronym STEM (Science, technology, engineering, and mathematics) was first coined in the late 1990s in the United States by the National Science Foundation. This is part of the political strategy produced by the United States as a form of global superiority (Blackley & Howell, 2015). STEM innovation is considered important for the economic future of all countries as it leads to innovation and global competition (Beede et al., 2011). Therefore, many countries are preparing a workforce in the STEM field. However, many challenges are faced in improving STEM-based education in both developed and developing countries (Caprile et al., 2015). STEM education is an integration of two or more disciplines whose learning focus is on authentic problem solving or product creation (Sanders, 2009).

Along with the development of STEM education, 21st century skills are generally used to refer to certain core competencies such as collaboration, digital literacy, critical thinking, and problem solving. Educators believe that these skills help students thrive in a global society (Partnership for 21st Century Learning, 2015). The International Society for Technology in

Education (ISTE) developed seven standards for students: empowered learners, digital learners, knowledge constructors, innovative designers, computational thinkers, creative communicators, and global contributors (International Society for Technology in Education, 2016).

The STEM approach invites students to learn contextually in dealing with problems directly. As in chemistry learning, students like authentic research-based practicum in solving real-life problems (Mutambuki et al., 2019). Under normal conditions, STEM is carried out in schools freely, so that students get direct experience. STEM projects can also increase students' involvement in creating and investigating their own experiments in real-world applications (Burrows et al., 2014).

The data showed that there is no significant change in students' intentions to pursue a career in science during the spring of 2020 during the Covid-19 pandemic (Forakis et al., 2020). According to Hwang (2020), no significant relationship was found between online engagement (i.e., written responses/feedback sent through the learning management system, referred to as LMS student feedback) and online achievement (i.e., final exams), This is because the involvement is more like formative assessment than active learning activities.

Online STEM learning has been carried out by several researchers (Erickson et al., 2014; Hachey et al., 2015; Johnson, 2019; Stoeger et al., 2013; Wladis et al., 2014, 2015) but during a pandemic, not many have researched on online STEM (synchronous & asynchronous) learning for university students. Thus, it is interesting to examine the condition of higher education students when studying with the STEM approach online in the pandemic era. This study is to determine the implementation of project-based STEM learning online. This study reveals the pre-service teacher's interest in STEM-projects, what knowledge pre-service teachers acquire, and what 21st century skills can be trained during the process of making STEM projects.

B. Methodology

Research Design

This research is a qualitative research that reveals why the phenomenon appears and how the phenomenon unfolds over time (Elliott & Timulak, 2005). This research is an action in implementing project-based learning with a STEM approach which is carried out with a Learning Management System (LMS), namely Schoology and assisted by other applications, namely Zoom Meeting and WhatsApp. The research was carried out in 7 stages in implementing learning with the STEM approach which included: (1) Identification of social issues, (2) Identification of potential solutions, (3) Need for knowledge, (4) Decision-making, (5) Development of prototypes. or product, (6) Test and evaluation of the solution, and (7) Socialization and completion decision stage (Fachrunnisa et al., 2021). This research is limited to the 5th stage, this is due to the limitations of the pandemic conditions, so mobility is very limited.

Participants

The participants are pre-service chemistry teachers in the second year who are taking Integrated Science courses at the Muhammadiyah University of Semarang, Indonesia as many as 16 students. One of the requirements to become a participant is the willingness to

complete all the required work targets. Based on the study there were only 15 respondents who met the qualifications. All respondents were asked to create a STEM-based project. Students are also given an open survey after participating in learning activities to reflect on learning activities.

Organizing Online Learning

STEM Project learning using a learning management system (LMS), namely Schoology, is carried out in May-July 2020. This allows students to successfully manage assignments, submit assignments, and track deadlines assuming appropriate instructions have been given. The navigation page shown in Figure 1. shows that the organization is user friendly, even for beginners. When first using the LMS, students only need instructions on how to submit assignments and discussions.

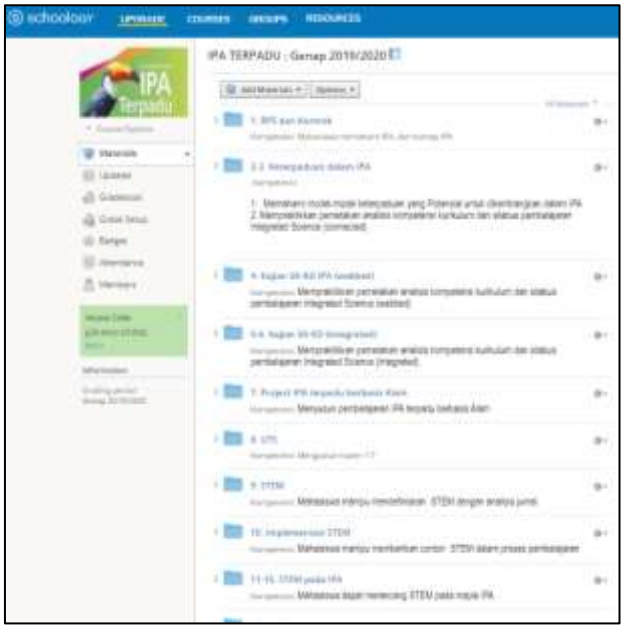


Figure 1. Navigation features in Schoology.

Data

The data include: The results of each STEM stage, student involvement, and STEM products (pictures & videos). An online-based survey was used on aspects of student engagement and scientific knowledge, including STEM product design drawings. Open-ended questions and observations were also given to verify student involvement. In the final stage, reflection on the STEM Project learning is carried out. The open questionnaire used was adopted on an open instrument (Blackley et al., 2018).

The survey used a Likert scale (1-5, 1: strongly disagree, 5: strongly agree). The survey consists of two items (1 and 2) which are statements requiring participants to choose from a Likert-type scale described by both numerical values (5 = strongly agree with 1 = strongly disagree). Item 3 has additional free text responses, and item 4 is free text. Item 5 asks participants to draw a STEM project diagram, and label it, to show what makes the project's product work. This research activity was conducted online at university level science

learning lectures for pre-service teachers. There are 16 students enrolled in this course. The learning activities in this study used a series of topics as shown in Figure 2.

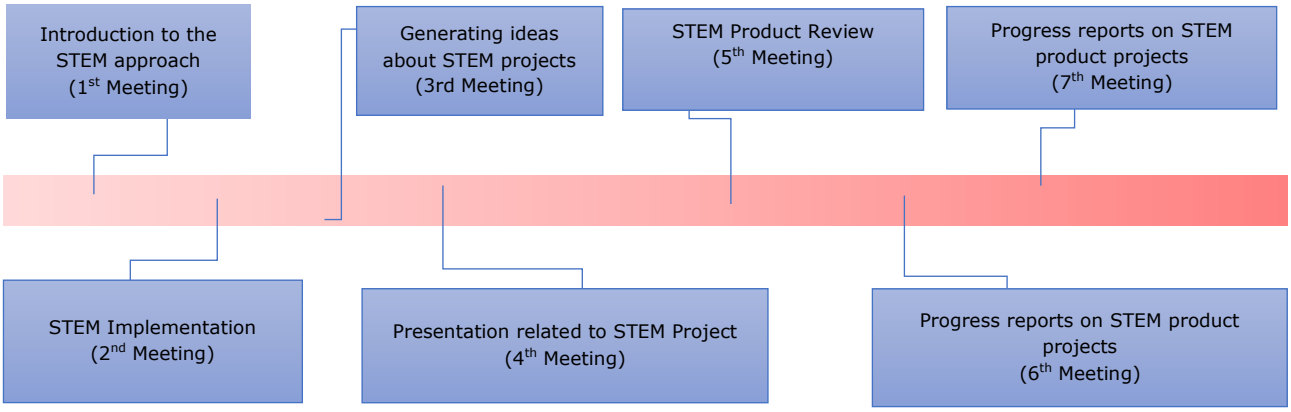


Figure 2. Learning stages related to STEM Project

C. Result

During the research process, several data were obtained, both responses and project products. The results of the survey of student responses to the STEM project can be seen in Table 1.

Table 1. Students' survey responses (Items 1&2) (N = 16)

	Statement	Strongly agree				Strongly disagree	Mean
		5	4	3	2	1	
1	I enjoyed the Project STEM activity	33%	40%	27%	-	-	4.0
2	I can see that this activity uses science knowledge.	67%	20%	13%	-	-	4.5

The completeness response inventory of participants in STEM-based processes and products is shown in Table 2.

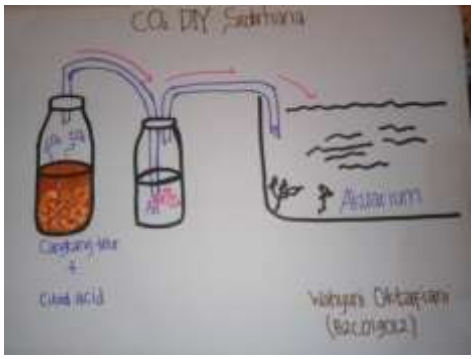
Table 2. Types of products from STEM projects undertaken by pre-service teachers

No	Name	Gender	Product Components			
			Video	Design	Description	Topic
1	LK	F	✓	✓	✓	Water filter
2	AD	F	✓	✓	✓	Liquid Organic Fertilizer from Waste Water Used to Rinse Rice
3	AS	F	✓	✓	✓	Alternative energy (battery) from banana peel
4	AF	M	✓	✓	✓	Aquaponics
5	BB	M	-	-	-	-
6	FR	M	✓	✓	✓	Citrus Fruit Picker
7	IQ	F	✓	✓	✓	Recycle Cooking Oil with Banana Peel
8	NU	F	✓	✓	✓	Simple Organic Mask
9	NS	F	✓	✓	✓	Pump from Paralon Pipe
10	OW	F	✓	✓	✓	DIY CO2 In Aquarium Aquascape
11	PA	F	✓	✓	✓	Water-saving Spray Tool
12	SS	F	✓	✓	✓	Automatic Sprinkler (Sprinkler)
13	SA	F	-	✓	✓	Oxygen Cylinder, Simple and Cheap Breathing Aid
14	SS	M	-	✓	-	Detergent water filter
15	TK	F	-	✓	✓	Simple Corn Fertilizer Tool
16	ZH	M	✓	✓	✓	Lemongrass scented cooking candle as a mosquito repellent

Diagram Product of Project STEM

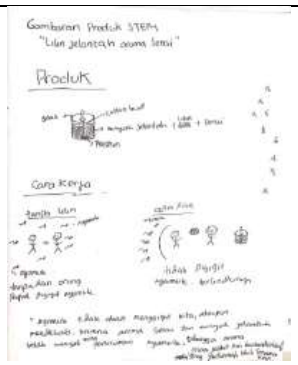
The participants' diagrams of project STEM were categorised based on the work of (Bowker & Bowker, 2007) **Breadth**: the labelled diagram shows component parts, do not indicate how the individual components work together, **Depth**: the labelled diagram shows component part, they are evident as a system. **Extent**: a working tools could be constructed using the diagram and labelling. **Mastery**: a drawing of a completed tools plus a diagram that shows depth plus a caption. There are 4 types of project product categories, here are some examples, presented in Figure 5.

Breadth



Depth

Extent



Mastery

Figure 3. Types of project product categories

The distribution of the product categories for the STEM project for prospective teacher students is shown in Figure 4.

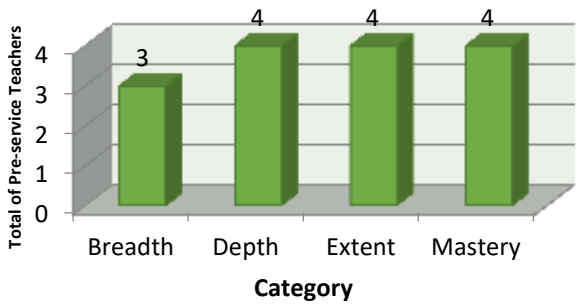


Figure 4. Product category conditions of the STEM project

Video and Description of STEM Project

Videos and product descriptions are STEM project-based learning outputs. Videos and descriptions are obtained from links collected by students. The function of these two products

is as a means of confirming product drawings and work procedures obtained from the STEM project. This is shown in Figure 5.

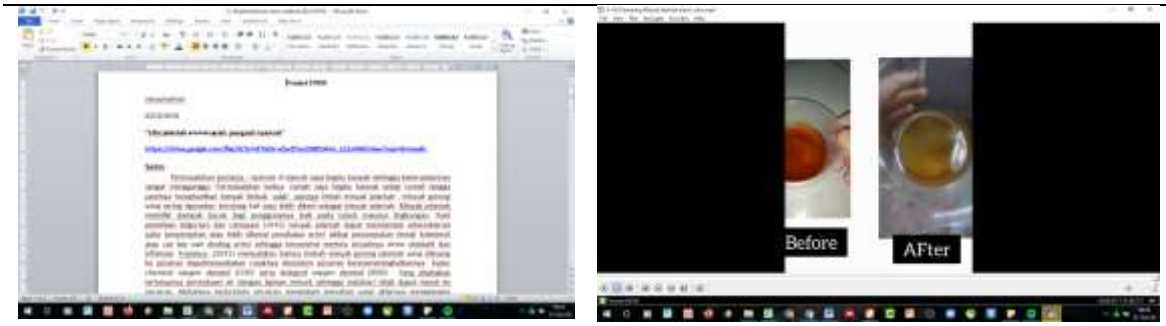


Figure 5. Description of STEM Project & Product manufacturing procedure

D. Findings

One of the important findings in the implementation of online learning based on STEM projects is the interest of students in participating in the learning process. This is based on the results of online surveys, STEM project products, open questionnaires, videos and STEM project diagrams.

Changes in the STEM Project-based learning model from offline to online

Due to the Covid-19 pandemic, all STEM project-based learning activities must be carried out online. Online learning activities are organized using an LMS, namely Schoology. In addition, online meeting activities are carried out using Zoom and Whats App. Basically, the following changes to the STEM project were carried out using a three-phase model, as shown in Table 3. So far, pre-service teachers have not experienced any difficulties in operating LMS Schoology, because the navigation is friendly to use.

Table 3. Changes in the STEM Project-based learning model from offline to online

No	three-phase model	Offline	Online
1.	In the explanation phase	Students are situated in groups (organised by the regular classroom teacher)	Instruction via Zoom
2.	Engagement and Experimentation phase	Engagement and experimentation phase: asking "What if?" by mentor	Discussion Via Zoom, Whats Apps
3.	Evaluation and Extension	Evaluation and extension, the students demonstrated their	Produk STEM

	working	Deskripsi produk Record how works Product

Students' engagement and self-confidence

The results of the study in the form of student interest in participating in learning were obtained by distributing questionnaires. To attract students' interest in this learning, an example is given to students, namely a star fruit picker product that has been made by researchers (Figure 6.). The examples are expected to inspire students to create design products based on the problems that surround them with the stages of learning STEM projects.

Figure 6. An example of a tool that is a product of a STEM project
https://www.youtube.com/watch?v=28u6WXitGh0&t=322s

The STEM stages are 1) Identification of social issues, (2) Identification of potential solutions, (3) Need for knowledge, (4) Decision-making, (5) Development of prototype or product, (6) Test and evaluation of the solution, and (7) Socialization and completion decision stage. The existence of real problems faced by students will help solve their problems directly. The meaningfulness of the topics studied based on STEM projects will be felt. This is shown from the pattern of students' involvement in Figure 7. Students are challenged to express their ideas and develop their knowledge and skills (Rahmawati & Taylor, 2014; Suprapto, 2016).

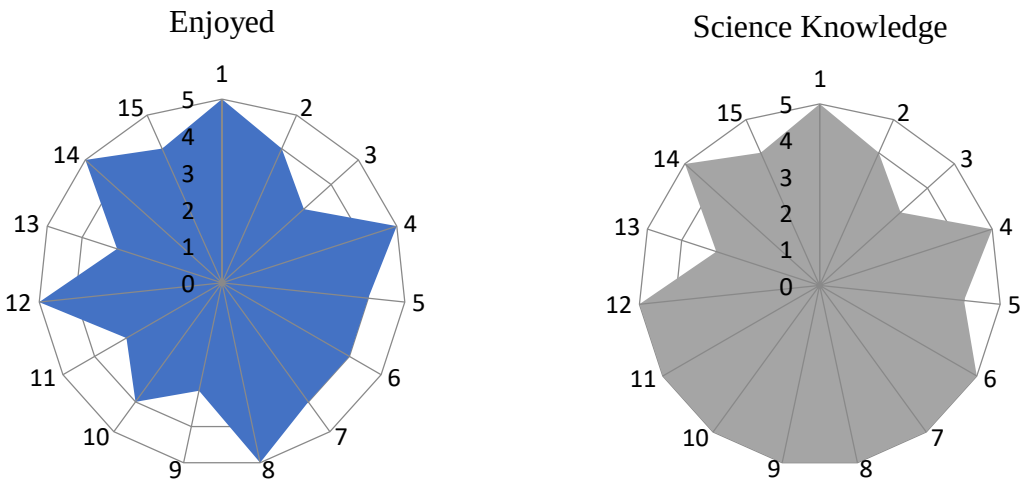


Figure 7. Students' engagement

Science knowledge and understanding

Pre-service teachers should have opportunities for not only developing their soft skills (e.g. collaboration, communication, and perseverance) but also knowledge and operational skills. In one of the questions on the instrument, pre-service teachers were asked to draw a diagram of the product so that it can operate properly. Students draw on paper and take a photo which is then uploaded to schology. Based on the categories of the students' drawings, the school students demonstrated their level of scientific knowledge and conceptual understanding – the categories of Breadth, Depth, Extent, and Mastery were illustrated in the Figure 6. In this STEM project, students have the freedom to choose topics, so the products are varied as shown in Table 4. There are 16 pre-service teachers who take lessons but only 15 people who complete the lesson to the end, a pre-service teacher can't finish the project well.

Tabel 4 Topics on the production process in STEM project-based learning

Categorisation of Topic	N
Environment	3
Agriculture	7
Energy	1
Health	3
Fishery	1
Total	**15**

Students' 21st century skills

During the STEM project-based learning process, students develop inquiry skills, questioning skills, problem solving skills through product development that is used in real life. In addition, the 21st century skills of prospective teachers are developed which include collaboration skills in asking questions, discussing, and team work. During the project completion process, pre-service teachers discuss with each other to make the product successful. There are 80% of pre-service teachers conducting discussions, and the rest do not conduct discussions. Discussion activities in online learning are carried out using WhatsApp or directly if they discuss with their closest family members.

E. Discussion

STEM is a learning approach that draws on the collective disciplines of science, technology, engineering and mathematics. This cross-disciplinary approach serves to increase student interest and problem solving. STEM approach learning is not aimed at harmonious integration between knowledge content and teaching only, but knowledge focuses on problem-based activities. Although this learning is not done face-to-face. One of the factors that support interest in learning is that pre-service teachers feel challenged by various kinds of problems in their daily lives. In addition, it is reinforced by several research results that this project provides various interesting experiences. STEM provides learning experiences in which students solve problems, reason, manage time, and use a variety of tools (Milaturrahmah et al., 2017). The following is one of the products that have been completed by pre-service teachers to solve the problem of mosquito bite disorders, which is fully presented in Figure 8.

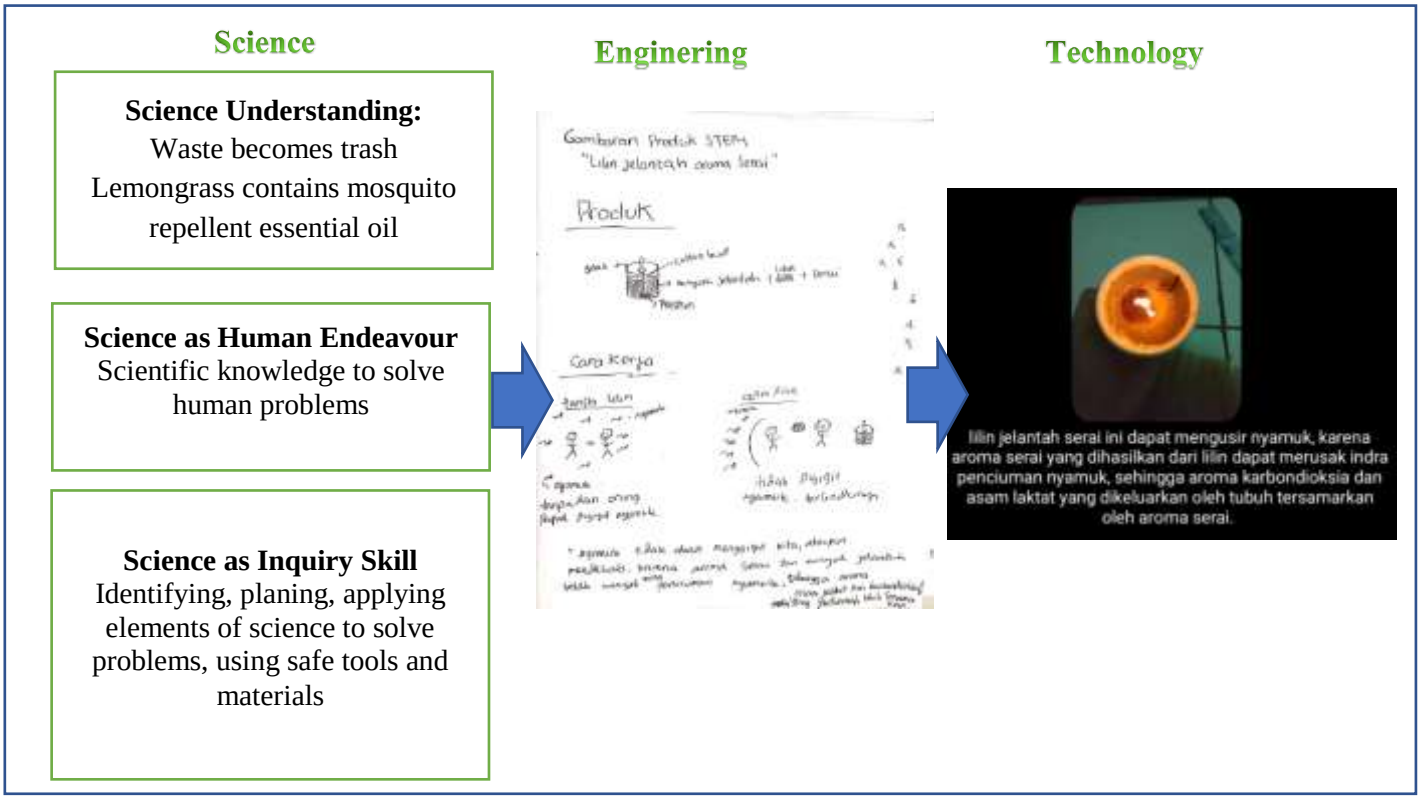


Figure 8. Concept of STEM on a project completed by a pre-service teacher

STEM learning does not only involve pre-service teachers with campus parties but is also set to various contexts such as homes, community-based activities, after-school programs, workplaces, museums, science centers, zoos and aquariums, as well as in various digital media (Dierking & Falk, 2016). STEM project-based online learning provides opportunities for pre-service teachers to interact more intensely with their families. Thus, it provides experience in problem solving through working with family members.

How effective was the *STEM Project* in supporting pre-service teacher engagement and self-confidence in STEM education?

The positive thing about the STEM-based project learning experience is the ability to solve problems. There are 12 students out of 16 who have completed the project well. Even though there was 1 student who did not complete the project due to family problems, so he was unable to complete the project. While 3 students did not complete the video, it was possible because of the lack of facilities they had, so they did not provide video evidence. Although the video is not made, product photos are reported and provide testimonials on the use of the products that have been made.

Pre-service teachers become accustomed to proposing ideas, analyzing problem conditions, deciding which ideas to develop, designing products, trying to design, experimenting, and presenting products with videos. All of this is a series of student abilities and confidence in completing projects. Although the product obtained is not perfect, they are confident in conveying the results as they have been achieved.

The ability to analyze problems in everyday life is very important. Using the stages of STEM learning, students are able to identify and provide solutions. Learning in this research is facilitated by LMS schoology which functions as a forum for giving project assignments at each stage. Meanwhile, Zoom is a medium for direct discussion and reporting on project progress. Various questions and discussions were also facilitated with WhatsApp, so that some pre-service teachers' difficulties during project completion could be resolved. The three media can already help in STEM project-based online learning.

What science knowledge and understandings did pre-service teacher demonstrate as the consequence of the *STEM Project*?

The survey results showed 67% of students said that in this STEM project, they must have extensive knowledge of science. Thus, they are expected to be more aware of how important it is to study other sciences, so that they can collaborate in solving problems. One of the students even said that there were interesting things that they experienced while doing the project. The expression is as follows.

> *"The most interesting part is in the engineering activities, in the trial error phase, where we will find shortcomings and then we will look for ways to get maximum results"*

This showed that they enjoy the project and continue to strive to improve product quality by learning other knowledge, so that maximum results are obtained.

What 21st century skills did pre-service teacher demonstrate as they participated in the project?

This STEM project is interesting for pre-service teachers, one of which is getting used to collaborating. As stated by one participant as follows:

> *"The first time my brothers and cousins wanted to help with my assignments, they usually just commented"*

This is an interesting finding in STEM learning, that it turns out that with projects, apart from teaching some things, solving problems, thinking critically, communicating projects, but also can bond family members. The STEM stage which is the part that requires collaboration is at the "Development of prototype or product" stage. In this study, the STEM project was carried out at home, so that one of the collaborative teams was a family member. The case of STEM learning during this pandemic is appropriate to be carried out in a blended manner by involving family members.

F. Conclusion

This STEM Project-based online learning is interesting for pre-service teachers in developing several products to solve their problems at home. During the completion of the project they also become aware of the need for knowledge during project completion. In addition, to support 21st century abilities, they find several skills, one of which is cooperation in completing projects.

G. Limitation and Future Studies

This research is a qualitative study with a limited number of respondents so that the wider impact is not yet known. In addition, this study uses Schoology, Zoom and WhatsApp, so the results can also be different if learning uses other media applications. There is a need for online STEM learning studies with wider participants, and using specific topics.

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