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Development of STEM-Based Interactive Digital Teaching Media Adapted to the Learning Trajectory of Prospective Teacher Students

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ABSTRACT: *The purpose of this study was to observe the learning trajectory of prospective elementary school teachers in the Thematic Learning course, then design a STEM-based teaching trajectory into interactive digital media. The output of this study is interactive teaching media that can be used by similar populations with appropriate learning trajectories. Advances in digital technology provide opportunities for the development of mathematics learning by providing a digital platform as an interactive media. Abstract mathematics learning requires various forms of representation, thus giving rise to various hypothetical Learning Trajectories (HLT). Furthermore, the hypothesis in the form of a prediction of the possibility of various student responses will produce a learning trajectory that can be fulfilled by interactive teaching media. The application of teaching media is also developed based on STEM, an active and participatory learning model from students. Teaching materials and learning models are closely related to being presented in teaching media so that learning can run according to the teaching trajectory. However, it is unfortunate that mathematics learning for prospective elementary school teachers does not always have media that is in accordance with the model and teaching trajectory so that instead of making it easier, it actually makes it difficult for students to use and obtain material. In addition, it provides a new reference source on mathematics learning with the STEM model reviewed from the learning trajectory of prospective teacher students. The media was developed with the RnD model of the ADDIE method, based on several aspects and obtained a feasibility score after being revised, namely; 1) Suitability of graphics and media (average = 3.89), 2) Suitability of Material (average = 3.75), 3) suitability of STEAM learning (average = 4), 4) Overall suitability of the web (total average score = 7.9), all of these aspects are in the category of very suitable for application in mathematics learning for PGSD students.*

KEYWORDS *-Web-based media, Thematic learning, STEM, Learning obstacle*

I. INTRODUCTION

Efforts to provide quality, effective, and efficient mathematics learning continue to be carried out. Starting from improving teaching materials, providing teachers, to updating the curriculum, improvements are continuously made (1). However, this is not easy, it requires in-depth analysis of various dimensions of learning, one of which is the learning trajectory. There are three main components in building a learning trajectory, namely learning objectives for achieving meaningful learning, tasks and exercises to achieve goals, and hypotheses about the conditions of how students' activities and ways of thinking are (2)(3).

Learning Trajectory (LT) can be used by teachers to determine the learning objectives to be achieved, the steps to start learning, the learning steps to achieve these objectives (Simon, 2020). Known as a learning

flow, namely a learning trajectory that describes the prerequisite knowledge that students already have, as a starting point in understanding the next material, obtaining an overview of the student's thinking process, the model to be used, to the level of thinking that students have achieved (1) (4). Educators act as facilitators who provide opportunities, teaching directions, materials and teaching materials to students so that they are able to build their own knowledge according to the needs and potential of students. The relationship between educators and learning trajectories shows that educators will be able to provide good learning facilities based on learning trajectories (5).

In Learning Trajectory (LT) there are two terms, namely Actual Learning Trajectory and Hypothetical Learning Trajectory (HLT) (6). Hypothetical Learning Trajectory (HLT) is an assumption designed by educators about the learning flow that might occur in the learning process in the classroom (Simon, 2020). The term "Hypothetical" according to Simon, because the actual learning flow cannot be known at the beginning, in other words the actual learning flow is only obtained after the learning process takes place. So, by making assumptions about the thinking that students will go through during the learning process, educators are required to prepare various models, strategies, and teaching materials that will be used during the learning process (7). Hypothetical Learning Trajectory (HLT) can help educators to apply the right models, strategies and assessments according to the stages of student thinking (8). Then, the Hypothetical Learning Trajectory (HLT) is also an assumption of learning activities made as an anticipation of what might happen in the learning process (8).

In the theory of learning trajectories, the selection of learning models and media is the most important thing. The selection of STEM as a learning approach can optimize mathematics learning. STEM is a fairly flexible approach applied to mathematics learning, namely learning by integrating aspects of science, technology, engineering and mathematics (9)(10). The success of STEM in mathematics learning at all levels of formal education. Supported by the use of technology and designing products in mathematics learning, learning with STEM improves students' understanding of mathematics (11). Further and more general research reveals that the STEM approach to education, seen from a pragmatic perspective, contributes to the development of skills needed in the 21st century, namely critical thinking skills, collaboration, leadership, mathematical modeling, and productivity (12) (13).

Mathematics learning with a STEM approach will be more optimal by using interactive multimedia. Media that can display sound, images, and can be operated can facilitate in-depth learning by actively involving students in the learning process (Lely et al., 2020). In general, the use of learning media generates new desires and interests, generates motivation, and stimulates learning activities, and brings psychological influences to students, it can be concluded that there is a relationship between learning media and technology which both have their appeal (14). Interactive multimedia has advantages so that it can be used as an alternative learning media in schools. The use of interactive multimedia can support the learning process so that it can improve student learning outcomes (14). In addition to increasing the effectiveness and efficiency of teaching, the use of interactive multimedia in mathematics learning, students are very enthusiastic and interested (15)(16).

Prospective mathematics teacher students have a high need for improving their mathematical skills and in-depth learning experiences. They are required to understand the material well because of the professional demands of teachers who require mastery of the material so that they can teach (17). In addition, as prospective teachers, mathematics education students are required to have a wealth of approaches, models, methods, and teaching techniques that can be practiced in the classroom later. However, prospective mathematics teacher students rarely get interesting and effective mathematics learning experiences (18). Based on initial observations, students are not familiar with the term learning trajectory so that the learning they receive is often not in accordance with the learning objectives stated in the lecture contract (19). In addition, the ongoing courses still apply the lecture method, are not student-centered, and only use learning media such as whiteboards or presentation slides.

Special attention is needed for courses taught to prospective teacher students, including calculus, spatial geometry, linear programming, and numerical methods that have received less attention from educators to be taught in an interesting way (6). These courses are integrated mathematical sciences that build branches of

applied mathematics, so that understanding the theories in them can be assisted by image media (20). Unlike other courses, namely pure mathematics, such as algebra, sets, real and complex analysis are materials that cannot be shown with real examples, because of their abstract and symbolic nature (21). The opportunity to present mathematics in the form of images, videos, and interactive media cannot be utilized in applied mathematics learning, thereby reducing the essence of meaningful learning. The complexity of mathematical material in higher education can no longer be taught with "hands-on" media, digital interactive media is needed that can be easily accessed and can accommodate the complexity of the material (22).

With the rapid growth of the internet, the web has become a powerful, interactive, dynamic, economical and democratic distance learning and teaching medium (23). The web provides an opportunity to develop learning and training that is in accordance with demands and is oriented towards the learner (learning centered) (24). The web is also a representation of a new paradigm regarding learning, especially how learning is organized and presented. Web-based learning or popularly known as web-based education (WBE) or sometimes called e-learning (electronic learning) can be defined as the application of web technology in the world of learning for an educational process (25). The use of the web as a learning medium is in principle the web is used as teaching material. Web-based teaching materials are teaching materials that are prepared, run, and utilized with web media (6). Teaching materials are also often called internet-based teaching materials or online teaching materials. There are three main characteristics that are the great potential of web-based teaching materials, namely; 1) Presenting multimedia, 2) Storing, processing, 3) Presenting information and hyperlinks (26). Because of its online nature, web-based teaching materials have special characteristics according to the characteristics of the web itself. Based on the various complexities that occur along with the progress of the times as well as the development of learning and various innovations involving learning media, researchers focus on problems in developing STEM-based digital learning media that are adjusted to the Learning Trajectory.

II. METHOD

The research method used in this study is Research and Development (R&D), which is a research method used to produce certain products using research that is of a needs analysis nature and to test the effectiveness of the product so that it can function in the wider community, research is needed to test the effectiveness of the product (8). The subjects of this study were prospective elementary school teacher students, while the location of the study was the Universitas Muslim Nusantara Al-Washliyah, Medan. In this study, the R & D method was used because the final result of this study will produce a product in the form of a website as a digital learning media in mathematics: numbers and statistics courses. The steps in research and development can be described as follows.

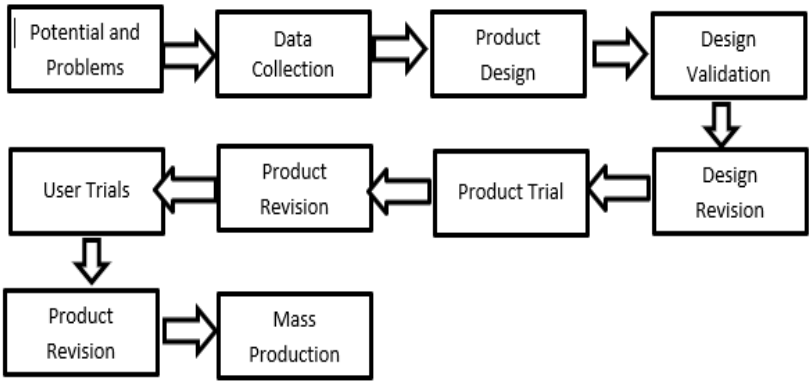

Fig. 1 RnD Flowchart

Of the 10 steps developed by Sugiyono, only 6 steps will be adapted in this study, namely steps 1 to 6. The following is a research flow diagram:

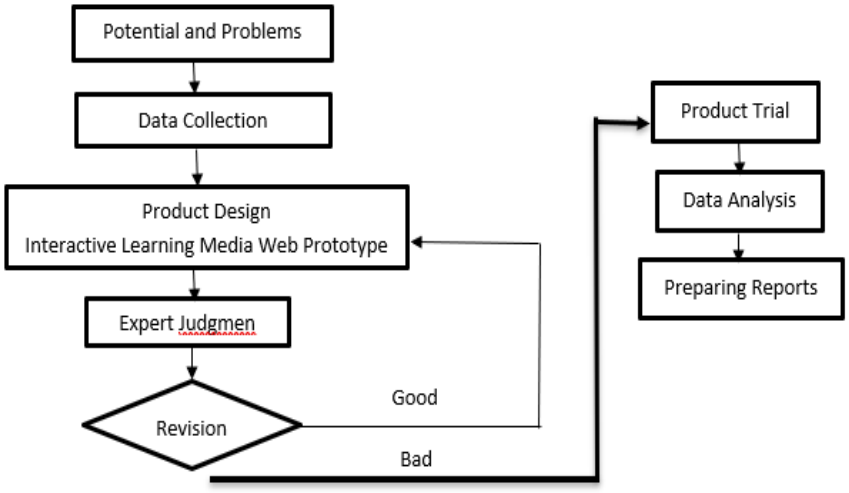

Fig. 2 Flowchart of Each Step

III. RESULT AND DISCUSSION

RnD research is to develop a product, this study develops web-based learning media provided in the learning of prospective teacher students in thematic courses. Provision of learning web as the main learning resource in achieving the competency of the course. In addition to producing products in the form of learning webs, the development process is described based on the steps of developing devices using the ADDIE method, namely; Analysis, Design, Develop, Implementation, and Evaluation. The product in the form of a web or also called web-based education (WBE) is adjusted to the learning trajectory. Development of web-based media using Visual Studio in HTML language is accessed via localhost offline assisted by XAMPP v3.2.2 on a LAN network. The description of each ADDIE stage is explained as follows:

Analysis Stage

Elementary School Mathematics Learning is a mandatory main topic for prospective elementary school teachers. This course requires teaching accuracy in terms of materials, teaching techniques, methods, and media. In addition to understanding the competencies to be taught, prospective elementary school teachers must also master good teaching techniques in order to be able to teach their students again.

The analysis stage is the initial step to obtain the main problems faced by students in elementary school mathematics learning. The methods applied in the analysis are identifying problems through direct observation, short questionnaires regarding student learning needs, interviews, and curriculum analysis. The questionnaire technique is by providing six questions with closed answers, then the answers are revalidated through interviews conducted with PGSD lecturers, Mathematics Education Lecturers, Elementary School Teachers, and PGSD students. Observation is also used to obtain the actual conditions of the implementation of learning and the condition of students. Internal and external conditions of students and teaching must also be adjusted to the curriculum applied in educational institutions so that the learning trajectory is well structured without jumps.

• Needs Analysis Questionnaire and Interview

The questionnaire was given to 22 students in the form of questions with closed answers, so that a learning needs analysis was obtained. Based on the questionnaire obtained;

Table 1. Student Learning Needs Questionnaire Answers

NO	QUESTION ITEMS	AGREE		DISAGREE	
		Student	**Percent (%)**	**Student**	**Percent (%)**
1	Enthusiastic in the learning process	17	77%	5	23%
2	Feeling difficult in learning	17	77%	5	23%
3	The use of media and learning resources will make learning fun.	21	95%	1	5%
4	Have ever used the Web as a learning medium	3	14%	19	86%
5	Learning uses the Web as a learning medium	17	77%	5	23%

The results of the student needs analysis questionnaire in Table 3, obtained 17 students or 77% enthusiastic about learning while 5 people or 23% were not interested. Furthermore, when interviewed directly with students with different opinions, students who were enthusiastic about the meta-course felt that the material taught was important as prospective elementary school teachers. In contrast to unenthusiastic students who considered the material taught was not in accordance with their competencies, thematic calculations had been mastered but they were not yet able to teach again. From this opinion, they argued that thematic teaching courses must be able to provide learning experiences and teach again to elementary school students.

Equivalent to the learning difficulties experienced by students, as many as 17 people or equivalent to 77% while those who did not feel any difficulties were 5 people or 23%. Students who felt difficulties in their interviews revealed that the difficulties faced were due to not understanding how to teach thematic again, but students who did not feel any difficulties only considered that understanding the material was enough. Students expect learning media to overcome the difficulties faced. This opinion was obtained from 21 students or equivalent to 95% and only 1 person or 5% considered it unnecessary to use media.

Students use learning websites when searching for materials or information during independent learning, not in class. So, there are 3 students or 14% who consider web media to have been used in learning, but the majority of students, namely 19 people or 86%, consider web media to have never been used in learning. Furthermore, students agree to use the web as a learning medium as many as 17 people or equivalent to 77%, the rest, namely 5 people or equivalent to 23% disagree. This difference of opinion is explained from the results of the interview that students who disagree think that learning using the web will make it difficult for students.

Based on the results of the questionnaire and interviews with lecturers, teachers, and students, some information was obtained, as follows: 1) Digital interactive media is needed that functions as a learning resource for students, 2) Digital learning media that is applied can be accessed cheaply and easily, 3) The presentation of material on the teaching media can be accessed anytime and anywhere, 4) Web-based learning media is a digital media that can be used on digital devices such as smartphones and PCs owned by students, so that it can be easily used, 5) Students expect learning resources that are easy to understand with or without lecturers accompanying them in learning, 6) The mathematics material studied by prospective elementary school teachers must be in accordance with the needs of teaching at the elementary school level, not too difficult.

• Observation

Researcher observation as a source of observation data is carried out in two aspects, namely observation of field conditions and learning documents. Based on observations in the field, namely teaching and learning activities in the classroom, the learning process is still student-centered even though the stimulus of questions is given by the lecturer but the response given by students is still low. Based on educational documents, namely curriculum books and teaching modules, often the material is not completely delivered in one semester. there are still learning jumps and learning trajectories that are not continuous between materials.

Based on this analysis, it can be concluded that the development of web-based teaching media is the focus of the problem in this study as the main problem. In addition, the media in question is able to be a source of independent learning for students with a learning trajectory that is adjusted to the needs of elementary school teachers (SD). Teaching media must also be able to provide learning experiences for students so that prospective teacher students can re-teach the material that will be taught at the elementary school level. In this study, the web-based learning media that will be developed is a learning source for the competency of Integer Arithmetic Operations.

Design Stage

The learning web design that will be built is a STEAM-based teaching media, namely using STEAM steps in the learning steps. The initial design of the learning web is shown as follows:

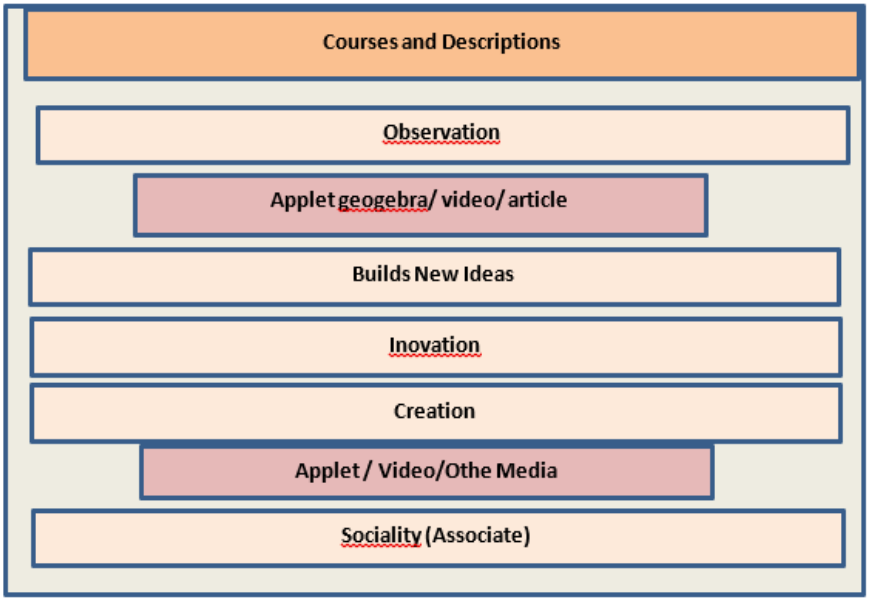

Fig 3. Initial web design map

Development Stage

Learning web media is built using HTML and CSS languages supported by learning media that support learning that can build learning trajectories or overcome learning trajectories. The web begins with a login or registration display to access the main menu of the web.

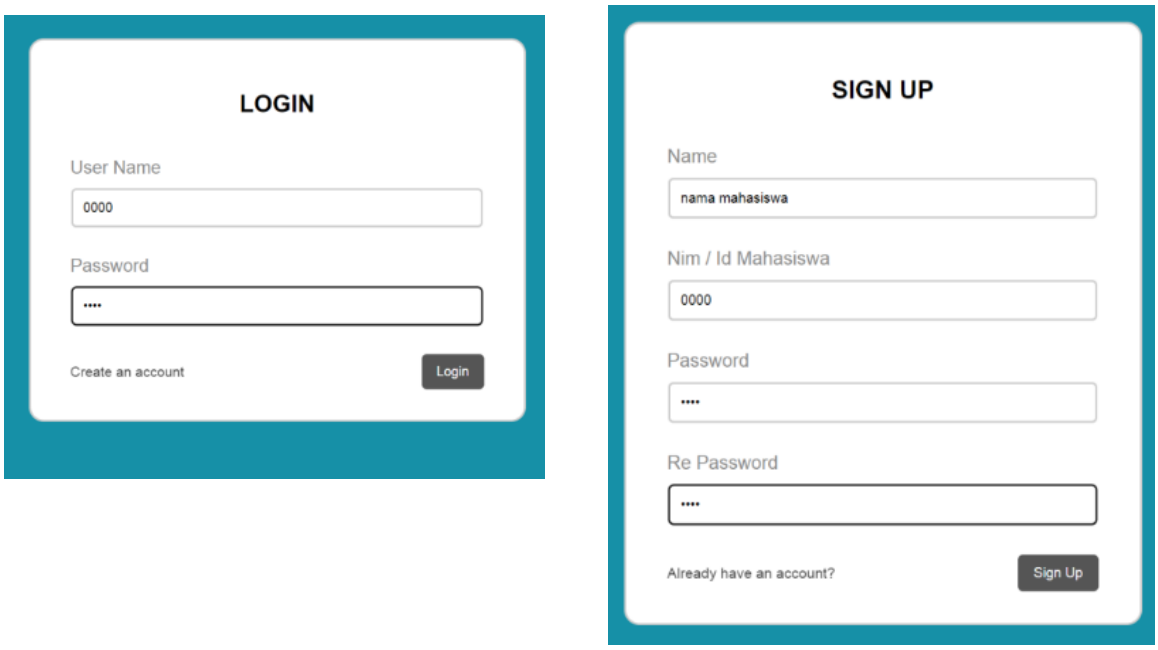

Fig 4. View of the login page (left) and account registration (right)

After successfully logging in, the main web page will be displayed containing the main title of the course along with the objectives of the course. On this page, users can access four main menus, namely materials, analysis, guided practice, and independent practice. In the material menu, it contains the materials that will be taught in the mathematics course for PGSD for one semester. In the learning readiness analysis menu, it explains the readiness of students to continue the material that will be taught, this aims to ensure that there are not a ontogenic obstacles and epistemological obstacles. The main display of the web is shown in Figure 5 below.

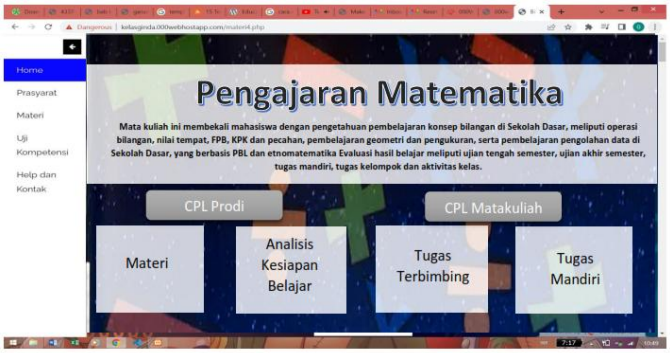

Fig 5. Main web view

If you enter one of the teaching material menus, namely integers, learning materials will be displayed based on STEAM steps, and equipped with interactive media such as geogebra applets, videos, or illustrations.

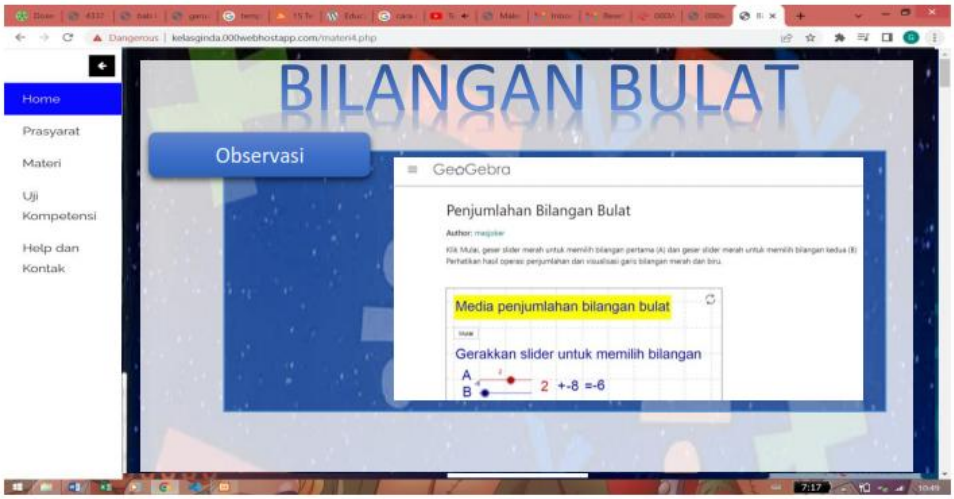

Fig 6. Display of one of the materials included in the Geogebra Applet

Implementation Stage

STEAM learning using web learning media was applied to 22 elementary school teacher education (PGSD) students in the Elementary School Mathematics Learning course.

Fig 7. Students access the learning website using a smartphone

Evaluation Stage

The evaluation conducted in the development of learning web media is media validation test, field trial, and direct observation. This evaluation describes the quality of the web from the development results, namely describing four aspects; 1) clarity of narrative, audio, animation, simulation, 2) suitability of material, 3) suitability of STEAM learning methods, 4) overall accuracy of the web media.

• Clarity of learning web

This aspect is evaluated from the perspective of two learning media experts, one of whom is an informatics lecturer who is considered an expert in developing learning webs and the other is a mathematics education lecturer who is considered to understand the use of web media in mathematics learning. The following are the assessment aspects and the results of improvements realized in the development of PGSD mathematics learning webs.

Table 2. Evaluation and assessment aspects

NO	ASSESSMENT ASPECTS	REPAIR	SCORE			
			Beginning		**Repair**	
A	**Graphic Display**		R1	R2	R1	R2
1	The front pages display is related to learning	Show learning objectives and CPL	3	3	4	4
2	Graphical display of each web page	-	4	4	4	4
3	Complete material according to the table of contents	-	4	4	4	4
4	The font size is appropriate and the color is clearly readable.	Adjust colors on dark background	2	3	4	4
B	**Multymedia**					
5	The media used is appropriate for explaining the material	The media is too monotonous, just pictures.	3	2	4	4
6	The illustrations presented are interesting	Find other illustrations that are relevant to everyday life	2	2	4	4
7	The media used is varied	Increase the use of Geogebra Applets, not just images or videos	2	2	4	3
C	**Practicality of operation**					
8	There are instructions for using the website	Add instructions for use	1	1	4	3
9	Ease of access	Accessible on PC and mobile with customizable display	2	1	4	4
	AVERAGE		2,5	2,4	4	3,8

There are special notes from the evaluator as final revision material, namely that the instructions for using the website should be explained more briefly and explain each menu or tool provided. Provide more interactive media than just images or videos. This aims to provide a more meaningful learning experience for students.

• Suitability of Material

The material presented is integers and their operations in the Mathematics I course for. The suitability of the material presented in the learning website was reviewed by two education lecturers, namely one elementary education and one mathematics education who had more than 5 years of learning experience. The assessment by the evaluator is as follows:

Table 3. Assessment of Material Suitability

NO	ASSESSMENT ASPECTS	REPAIR	SCORE			
			Beginning		**Repair**	
A	Eligibility of material/content		R1	R2	R1	R2
1	Compliance of material with CPL	Adjust to the CPL Study Program at the research location.	4	3	4	4
2	Suitability of materials to learning objectives	The objective specification is only on the bisection material	2	3	4	4
3	Accuracy of material	Complete with prerequisite material, namely the limit of containing solutions and approximate values before discussing bisection.	1	3	3	4
4	The material uses appropriate examples	Examples are accompanied by illustrations, not just narration.	3	2	4	4
5	Short, concise and clear material	Use clear and precise language	3	3	4	4
FEASIBILITY OF PRESENTATION						
6	Presentation of coherent concepts	Include prerequisite materials	2	3	3	4
7	Availability of exercises	Provide guided practice and independent practice. Practice using everyday problems.	2	2	4	3
AVERAGE			2,4	2,7	3,7	3,8

Both evaluators provided input to further improve the accuracy of the suitability of the material in the learning web. One of them is to consider the learning trajectory of the material, namely the material presented must be sequential or coherent. Steps and alternatives are given in completing mathematical operations, especially multiplication and division. In addition, each calculation is accompanied by mathematical reasons for each operational step to avoid learning obstacles (didactical obstacles).

• Suitability to the STEAM learning stage

The learning web media adapts STEAM learning, namely internalizing the STEAM syntax in the web. The evaluators are elementary education lecturers and mathematics education lecturers who have more than five years of teaching experience, so that the following evaluation results are obtained:

Table 4. Suitability of Learning Models

NO	ASSESSMENT ASPECTS	REPAIR	SCORE			
			Beginning		**Repair**	
A	STEAM Compliance		R1	R2	R1	R2
1	Conformity of observation stage	Use problems that are close to everyday life as observation material.	2	2	4	4
2	The appropriateness of the stage of building new ideas	Collect student answers or opinions using Google Forms	2	3	4	4
3	Conformity of stages	give students the freedom to build new	2	3	4	4

	to achieve innovation	ways of mathematical operations				
4	Student suitability creates creativity	guide students to build new ideas	3	3	4	4
5	Suitability of students to carry out associations		4	3	4	4
		AVERAGE	2,6	2,8	4	4

Special evaluation given by the evaluator in the suitability of learning web media using STEAM learning steps is for the innovation and creation stages. No instructions have been found that can stimulate students to obtain innovation so as to create creations. Further exploration must be carried out so that students are able to achieve these activities. One of them is by creating new calculation steps from existing steps. For example, in multiplication calculations, there are many known downward multiplications, multiplications with line methods and others. Students are required to create new calculation creations by introducing the associative properties of mathematics, namely multiplication and addition.

• Overall web media accuracy

After the learning web passed the evaluation results by several experts based on display indicators, material suitability, method suitability, the web was displayed in direct learning of integers and operations to 22 students. The accuracy of the web media was assessed using a questionnaire with answers of agree or disagree through 10 statement items. The results of the overall web media accuracy assessment questionnaire are as follows

Table 5. Overall Assessment

NO	QUESTION ITEMS	AGREE		DISAGREE	
		Student	**Percent (%)**	**Student**	**Percent (%)**
MEDIA ATTRACTION					
1	Attractive web appearance	17	77%	5	23%
2	Instructions for using the media are clear	8	36%	14	64%
3	Multimedia (images, videos, applets) are displayed clearly	18	82%	4	18%
4	The combination of images, text, background colors is harmonious	22	100%	0	0%
5	The website is easy to operate	20	91%	2	9%
MATERIAL SUITABILITY					
6	The material presented is appropriate	22	100%	0	0%
7	Practice questions according to the material	22	100%	0	0%
8	Using easy learning language or instructions	20	91%	2	9%
9	The material is related to everyday life	15	68%	7	32%
10	Makes learning easier by using the appropriate website	10	45%	12	55%

Based on the main aspect of the attractiveness of the web, it is considered disagreeable to the statement of the clarity of the instructions for using the web. As many as 14 people or 64% do not agree that the web has clear access to instructions so that it is difficult to use the web without a lecturer's guidance. In addition, based on the aspect of the suitability of the material, the learning web is still considered insufficient to facilitate learning by 12 people or 55%. Furthermore, the researcher conducted interviews with several students and lecturers, students felt that learning would be more effective and take a relatively short time if the lecturer explained directly. The time to access the web page must also be considered because of network constraints that are not always good and fast.

When teaching, teachers are often faced with a problem or issue - issues related to how to facilitate student learning. As students, prospective teachers need to provide and think about the ease of conveying information, on the other hand, students who get the ease of receiving information will learn more diligently and enthusiastically. In terms of helping students get the ease of obtaining information in their learning, there are many elements that must be considered. These elements are the objectives to be achieved, characteristics of students, content of the material being studied, methods and strategies to be used, measuring or evaluation tools, and feedback(27) (16).

As stated above, the elements that influence students to facilitate them in obtaining knowledge or information. One of these elements is learning media. The level of importance of the presence of learning media certainly depends on the purpose and content or substance of the learning itself. Media has various roles in learning process activities. So far, learning certainly depends more on the presence of teachers, but it cannot be said that the existence of media is not used by teachers, but other conditions, of course, media is used only as a tool in learning. This view suggests that there is no effort to empower media in the teaching and learning process (28). Learning may also not require the presence of a teacher if the media is used regularly. Learning that does not depend on teachers is also called "self-instruction", and is often directed by whoever designed the media. In a learning situation that is based on teachers, instruction-based instruction, the use of learning media in general is to provide direct support to teachers. Adequately designed learning media can improve and advance learning and provide support for teacher-based learning and the level of effectiveness of learning media depends on the teacher himself (29)(28).

Media and learning are inseparable things, because if the two are separated, they will be contradictory, then the learning process will not run well, besides the results or output in the learning process will also be less than optimal (30) For example, if a teacher teaches in an elementary school / MI class about rain, then in the learning process students will be made to imagine because the teacher cannot make media about rain, then the learning process will be less enjoyable, the teacher can only tell stories in theory, but students who are still at elementary school / MI need concrete things. If reviewed more deeply, the results of understanding from the learning process that does not require or does not use media will be very far (7).

Seeing things like that or current phenomena, teachers should be good at making all media, whether it is print, electronic, visual or audio media, all of which will have a significant impact on student understanding (26) (27)(31). The government has distributed learning media to all schools starting from the lowest level of RA/TK to the highest level, all of which have no other purpose than to make the learning process more enjoyable and students understand faster (4)(25).

Based on the description above, media and learning cannot be separated from each other, both must run together so that the learning process becomes more meaningful and students can understand and absorb the material taught by their teachers more quickly, besides that the material and media must be appropriate, because if the media used with the material delivered is not integrated or not connected then the learning process will be chaotic, for example if the teacher teaches about sea water then the teacher should not make media outside of sea water, for example stones, or stoves that are the media, all of that does not support each other between media and material (32)(24). So, media and material must support each other and go hand in hand.

IV. CONCLUSION

The conclusion obtained in the implementation of this study is that the development of STEAM-based learning web media can be applied in mathematics learning for PGSD students, especially in the material of integers and their operations. The feasibility of the developed web was evaluated based on several aspects and obtained a feasibility score after being revised, namely; 1) Suitability of graphics and media (average = 3.89) in the very appropriate category, 2) Suitability of Material (average = 3.75) in the very appropriate category, 3) suitability of STEAM learning (average = 4) in the very appropriate category and 4) Overall suitability of the web (total average score = 7.9) in the very appropriate category.

Suggestions that can be given after the implementation of this research are; to research with similar themes and populations, namely web development is carried out by experts, although it can be studied by researchers, this will take a long time. For other studies, learning webs can be reviewed by applying them to improve mathematical abilities, such as reasoning skills, problem solving, creative thinking, or mathematical communication. Meanwhile, for users, learning websites can be adapted for lower grade students by utilizing appropriate media or applets.

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