Journal for the Education of Gifted Young Scientists, 8(3), 1173-1184, Sept 2020
e-ISSN: 2149- 360X
jegys.org

youngwisepub.com

Research Article

STEM education at junior high school mathematics course for improving the mathematical critical thinking skills

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Article Info

Received: 28 April 2020
Revised: 19 June 2020
Accepted: 24 August 2020
Available online: 15 Sept 2020

Keywords:
STEM
Mathematical critical thinking
Mathematics course

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Abstract

The development of learning models based on integrated STEM lower secondary education projects has not yet been carried out. The integration of STEM into education is necessary because the high demand for human resources in 21st century STEM mastery-based learning provides space for students to choose activities to be carried out during learning, it also presents great opportunities for teachers to observe activity in developing student abilities. Quantitatively, an integrated project-based STEM learning model can improve students' critical thinking skills in mathematics in junior high school. In this regard, this study aims to develop project-based teaching materials that present mathematical topics combined with other STEM field teachers. The research method used is research and development. In this study only carried out at the stage of testing the validity of teaching materials that have been developed. Data collected during the study are material content validity evaluation sheets, advance validity, and construct validity, as well as conclusions on the feasibility of teaching materials. The data obtained were tested using Q-Cochran. The results showed that the integrated Project-Based Learning STEM teaching materials had passed the pace of development, an examination by judicial experts, and expert media testing to validate teaching materials. The validation results show that the face validity and the content validity of the teaching materials are valid and feasible. Then the results of construct validity are included in the validity of very good to very good. Then the validity of each item on the evaluation shows the high validity of the dominant values. It can be concluded from this study that the teaching materials developed have high flexibility, the instructions contained in the teaching materials are easily understood by students, and are suitable for use in a limited scope.

To cite this article:
Priatna, N., Lorenzia, S. A., & Widodo, S.A. (2020). STEM Education at Junior High School Mathematics Course for Improving the Mathematical Critical Thinking Skills. *Journal for the Education of Gifted Young Scientists*, *8*(3), 1173-1184. DOI: http://dx.doi.org/10.17478/jegys.728209

Introduction

The development of information technology and today is very rapid (Cash et al. 2003; Uranga, 1999). Ease of access to information from anywhere to make the flow of information in this world as there is no limit. The world's deployment trends are shrinking. Changes that occur in any field anywhere in the world can easily know. Flow influence of positive trends even faster and easier to follow and emulate. These trends occur in all aspects of life. From the start until the problem is lifestyle education also has its tendency prevailing at a particular time. Trends in education are very dynamic, it adapts to the needs of education that not only prepare students to know but also prepares students to have the skills to be used in life after graduating from the formal school level (Ghavifekr et al. 2014; Ott & Pozzi, 2011; Widodo et al. 2020). Many of the world trends that influence education policymaking in Indonesia. One of them is being intensively discussed in the world of education is the trend of the 21st-century learning demands of the 21st century learning implementers capable of learning to produce graduates with the competencies of the 21st century even explicitly described in the curriculum of 2013, there is a paradigm shift in the

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21st-century learning must be completely controlled by implementing learning to prepare students to compete in the 21st-century life (Dede, 2007; McLachlan, 2012; Rathsack, 2012; Salpeter, 2003; Siddique et al. 2012; Zubaidah, 2016).

One paradigm shift 21st-century learning is learning geared to encourage students to find out from a variety of sources, not notified (Morrison et al. 2010; Woocher, 2012). The role of the teacher is no longer a centre of learning (Hannafin & Land, 2012; Wright, 2011). Directed learning so that students actively seek learning experience of dish-dish that had been prepared by the teacher. The dish prepared by the teacher no longer be delivered only in verbal form, so that the students just listen and be passive during learning. The learning experience by listening only gives 20% of knowledge that should be acquired (Dale, 1946). So to improve student learning, the instructional design provided must change the role of students in learning. The passive role of the student should be directed to become active through a series of learning designs prepared by the teacher.

Project-based learning is a dynamic learning approach where students are actively exploring real-world problems, challenges, and gain deeper knowledge (Bell, 2010; Kricsfalusy et al. 2018; Wiek et al. 2014). The main characteristic of this project-based learning is directed learners and engage learners in finding the concept of discipline through a constructive investigation (Gülbahar & Tinmaz, 2006; Yadav et al. 2011). This characteristic is by the paradigm of 21st century learning in the Project-based learning Current research shows that the project can increase students' interest in Science, Technology, Engineering, and Mathematics (STEM) for the STEM engage students in authentic problem solving, cooperation among students, as well as develop the ability to create real solutions (Fortus et al. 2004, 2005; Han et al. 2015; Sahin, 2013; Scarbrough et al. 2004; Tseng et al. 2013). STEM also one of the important issues in the life of the 21st century. Inadequate education in math and science has led to a shortage of quality labour force resulted in a gap in the field of global industry, STEM emerged as the theme of the education reform movement to foster a skilled workforce in the STEM fields (Rush, 2016; Tanenbaum, 2016; Verma & McKinney, 2009).

Project-based learning is no longer a new thing for implementing learning in Indonesia in general. The project-based learning included in one of the models suggested in the curriculum in 2013 for use during the learning process. However, not all subjects can easily use the lesson plan for project-based learning. Learning is more commonly used in the subject of science rather than on the subject of mathematics. One challenge to using project-based learning in teaching the topics contained in mathematics. Not only has the project-based learning, the integration of STEM learning in schools Indonesia not been intensively conducted. Mostly new to the research stage and not yet widely disseminated regarding this STEM learning. The integration of STEM in education be things that need to be done given the high demand for natural resources master STEM in the 21st century.

Instructional materials are all kinds of materials that are used to assist teachers in implementing the learning process in class (Trisniawati et al., 2019; Widodo, Rahayu et al., 2018; Widodo et al. 2017; Widodo et al. 2018). The use of these materials is intended for students to play an active role in collecting information by the grain contained in teaching materials. Teaching materials commonly used are by using textbooks. However, in this case, teaching materials in question is a mathematical model of teaching materials and integrated STEM with project-based learning. These relatively new teaching materials especially in math and the possibilities to be found in ordinary textbooks are very rare. So, it takes a study on the development of teaching materials by the project-based learning and can accommodate STEM learning. Then after the new teaching materials are prepared, the important thing is to do the validation. Validation is done to produce valid teaching materials.

Problem of Research

Problems in this study include the ability to think critically students are still low, even though the ability to think critically is one of the important abilities that must be possessed by students in addition to the ability to solve mathematical problems. To face the 21st century as it is today, project-based learning is considered to be able to improve the ability to solve mathematical problems, improve students 'thinking abilities, and students' interests. Also, problems in learning mathematics in the 21st century include how to integrate mathematics into the concepts of science, technology, and engineering, or more commonly referred to as STEM. In connection with these conditions, it is necessary to develop a project-based learning model by integrating STEM to improve critical thinking skills. To develop the learning model, the first step that must be taken is to develop learning tools such as teaching materials that can be used in the learning model. For this reason, the main research question that arises in this study is "Are teaching materials for project-based learning models by integrating STEMs appropriate to use?".

From the formulation of this main problem, the sub-research questions are followed:

- How are the developed face validity and content validity of teaching materials?
- How the construct validity of teaching materials was developed?

Method

Research Design

Teaching materials developed following the development stages of the research model Research and development, where procedure consists basically of two main objectives, namely to develop the product and test the effectiveness of the product (Borg & Gall, 1996; Thiagarajan et al. 1974). In general, proposed 10 steps in the approach to R & D, namely: (1) Research and Information Collecting; (2) Planning; (3) Develop Preliminary Form of Product; (4) Preliminary Field Testing; (5) Main Product Revision; (6) Main Field Testing; (7) Operational Product Revision; (8) Operational Field Testing; (9) Final Product Revision; and (10) Dissemination and Implementation (Gall et al. 2007).

In this research, only the eighth step is the step of testing the operational area. In the initial stage of the field, testing consists of two activities, namely the validation of teaching materials and small scope test. The validation of teaching materials is the process of determining the validity of teaching materials conducted by judicial experts, media experts, and linguistic experts to see the product's language. The validity of teaching materials is seen from three aspects: face validity, construct validity, and content validity. A small scope test is conducted to see the validity of the teaching material products for users, in this case, our students.

Participants

Participants in this study were adjusted to the objectives of the research at the Operational Field Testing stage which consisted of two activities, namely the validation of teaching materials and a small scope test. In the activity of validating teaching materials on research participation were 3 people who were experts and not students. They were chosen using a purposive sampling technique. This side-taking technique is a sampling technique chosen based on the consideration of researchers to be relevant to the design of the research to be conducted (Creswell, 2012b, 2012a). Some considerations used in this section include the expertise of participants in the field of judicial experts, media experts, and linguistic experts to see the product's language. For small scope testing activities, research participants were 36 students of class IX in one of the junior high schools at Bandung. They consist of 17 male students and 19 female students; they are between 15-16 years old. Similar to validation activities, the selection of research participants in this activity uses purposive sampling where subjects were taken based on the characteristics of the same academic abilities.

Procedure

Research on the validation phase of teaching materials and limited trial stage conducted in March 2019 and carried out for 6 months. The stages in this study consisted of two stages, namely expert validation and limited-scale field trials. In the first step, the validator is to provide an assessment of the STEM instructional materials for project-based learning. If an improper assessment is obtained from the validators, the product of teaching material needs to be revised based on input from experts in the field of judicial, media experts, and linguists. In the second step, if the validators provide a good assessment of the instructional materials of the integrated STEM instructional materials project-based learning developed, the research team will test the product to students. This trial was conducted on a limited basis to see the shortage of teaching materials that were developed.

Data Collection Tools

The research data were obtained using the assessment sheet material (validation sheet) which included in it is the assessment of content validity, face validity, and construct validity, also the conclusion sheet the feasibility of teaching materials.

Assessment Sheet Material

The instruments used in this study were the validation sheet and the mathematical critical thinking test. The validation sheet is used by the expert (validator) to assess the instructional materials being developed. This teaching material validation sheet was adapted from an opinion Widodo (2017) and Widodo et al. (2017) which consists of 9 items, namely (1) suitability of instructional materials with basic competencies and indicators, (2) accuracy of the instructional materials, (3) up-to-date of instructional materials, (4) clarity of description of the discussion on instructional materials, (5) illustrations used in instructional materials, (6) ease of use of instructional materials, (7) suitability with the learning model to be used, (8) Language used in instructional materials (communication teaching materials), (9) Clarity of instructions or directions on instructional materials. Meanwhile, the mathematical critical thinking test consists of 4 questions in the form of a description. This question must be done by students after learning mathematics using PBL integration with STEM at the limited trial stage.

Data Analysis

Table 1.
Interpretation of Correlation Coefficient

Interval	Interpretation
$0.90 \leq r_{xy} \leq 1.00$	Very high
$0.70 \leq r_{xy} < 0.90$	High
$0.40 \leq r_{xy} < 0.70$	Medium
$0.20 \leq r_{xy} < 0.40$	Low
$0.00 \leq r_{xy} < 0.20$	Very Low
$-1.00 \leq r_{xy} < 0.00$	Invalid

After data about content validity, face validity, and construct validity tests are obtained, then an analysis using Q-Cohran. Q-Test testing criteria Cohran is H0 if the value of the Q-Cochran (x) is smaller than the value χ^2 the chi-square table with $\alpha = 0{,}05$. Besides, the determination of the validity of the items on the evaluation of teaching materials using software Anates. Determining the validity of the items is done by calculating the validity coefficient (r_{xy}). Here is the interpretation of the correlation coefficient of the level of validity as in table 1 (Parish & Guilford, 1957).

Results and Discussion

Early Learning Material Development

Table 2 shows the data STEM instructional materials development process with the model project-based learning. The data analysis was conducted by researchers begins at baseline. Results presented an overall reduction of the data obtained by researchers for researching the field development. Preliminary observations regarding STEM learning carry out by researchers during the learning process STEM at two junior high schools in the city of Bandung. Using the same materials in the junior math topics, as well as the value of the flexibility of teaching materials are made to be high enough.

Table 2.
Development of Integrated STEM Instructional Materials Project-Based Learning

Process	Contents
The collection of data and information	- STEM learning Observations
Plan	- Collecting draft instructional materials the same topic; - Learning the syntax analysis; The design of learning situations; - Determining the STEM fields that are integrated with each activity
Manufacture of products	- Formulate learning objectives and constraints of each activity material; - Creating a mathematical concept map; Starting from the real situation and contextual (Science); - Provide basic questions that are relevant to the observations; - Train the students' skills using simple tools or technology products; - Give the problems that are solved by product design students; - Give the question of mathematical concepts derived from products; - Dig up information on student understanding in selecting information.
Trials small sphere	- Analysis of students' initial ability; Power analysis supporting student learning activities; - The design of the different situation of each meeting

Process	Contents
Evaluation and Revision	- Observation of students' interest and enthusiasm for learning; - Interview impression after learning; - Analysis of the student's portfolio; - The impression of researchers for research; Revision of teaching materials

Results from the study showed children were capable of high enough will have a higher resistance to the duration of time learning and more likely to fulfilling not only one activity in one meeting. Later it was found also, strictly control the classroom environment can add to the concentration of students during the learning. Creating an advanced orderly classroom environment that makes students focus on learning. Designing table and seating positions in groups or ensuring students to sit in their chairs are very trivial, but in this study, it was revealed that these small things had an impact on learning conductivity.

The design of teaching materials prepared by the study curriculum. Project-based learning is a learning model contained therein. The distinctive feature of this model is the result in the form of the product. Not all topics in mathematics can be used as a real product. In preparing the draft, the researchers tried to bring out the characteristics of project-based learning. The characteristics of project-based learning are centered on the learner (Lou et al. 2011; Murphy & Gazi, 2001; Priatna et al. 2019). Teachers act as facilitators and provide scaffolding when students' difficulties. The amount of time spent by teachers to deliver material that uses the traditional approach does not occur in this model. So that the learning time or the researchers themselves more and focus on the observation of students during the learning. Another characteristic of project-based learning is to support cooperative learning through communication, exchange of information, knowledge, and opinions among learners (Priatna et al. 2019). The design of learning situations in line with these characteristics are studied in groups. By exchanging information to solve a given problem, teachers can observe students' ability to reason, choose the information and decide on actions to solve a given problem, the students' abilities as critical thinking skills (Krisdiana et al. 2019). The ability to think logically or critical thinking is part of the skills practiced during the learning of STEM (Bybee, 2013; Ostler, 2012; Rush, 2016). It should be added, the ability to think critically is a core capability of the competence of the 21st century published following the 4Cs P21 (Vockley, 2009). This ability is the output that appears during the study done.

The realization of the model project-based learning in this draft does not necessarily take a syntax that is already contained in the curriculum. Some of the considerations made to get the syntax of project-based learning following the frame of STEM learning. By benchmarking syntax project-based learning put forward by the experts and the syntax of project-based learning in the curriculum in 2013, researchers decided to use project-based learning elaborated syntax of the statement of experts. This is because there are points that the researchers highlight the syntax K-13 who are less able to facilitate learning efficiently. Thus, the project-based learning elaborated syntax of the statement used in the drafting of a lesson plan and teaching materials are then integrated with the STEM fields of choice.

Science and math are subjects that are part of the curriculum of 2013. While the subjects of technology and engineering techniques just to be a part of subjects' specific expertise was not even in the basic education curriculum. Therefore, the only STEM education is concentrated on science and mathematics. Through this teaching material, the selection of technology and engineering in the field of learning is done on the simple things first. In this study was not to design the technology but quite on the use of technology and do the project of making the product as an effort in the introduction of technical fields.

Integrated approaches to STEM ideally suitable, but in practice, the embedded approach considered more suited to do. In the embedded approach, one used as a field content major (Henderson et al. 2011; Roberts & Cantu, 2012). Major Field in the development of these materials is the field of mathematics. The integrity of the subject mathematics is maintained from beginning to end. Other fields of STEM sought to do with the main material. At the end of the material being evaluated or assessed is the matter of mathematics. So, no wonder the evaluation section contains only a mathematical concept.

Evaluation of Instructional Materials Development

Figure 1 shows the results of a project conducted by students through the initial design was then made products. Student product designs that result from gathering information for learning are written in the portfolio contained in Figure 1. In the image shown above is the result of activities undertaken by some groups of students who got the tools and materials that can be made into the above products. There is also another group by setting to make other

products with different materials but still, use the same concepts found the existence of different obstacles. Based on this, the researchers concluded that the activities would be more effective to use materials with the same activities for all groups of students.

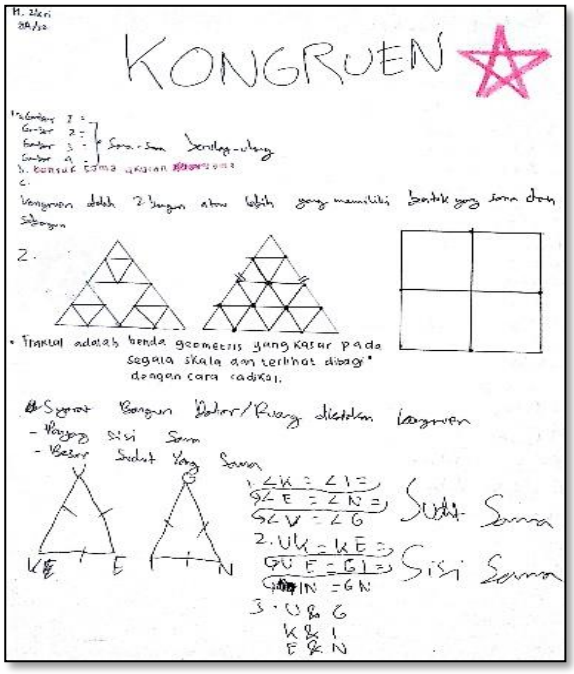

Figure 1.
Student Portfolios

Student activities are also analyzed when students were asked to choose the STEM fields that accompany the field of mathematics. The amount of the distribution of different groups makes teachers less can condition classes will be overwhelmed when a lot of questions from students about the vagueness of the instructions in teaching materials. This is similar to classical learning where the teacher must provide learning to students in large numbers. In conventional learning, the teacher has full control during the learning process (Khabibah & Sulaiman, 2018; Kibuku & Ochieng, 2019; Wongsri, 2010). If the teacher is not able to control learning, students become difficult to control and students become busy in the class (Asmar & Delyana, 2020; Cheon & Reeve, 2015). But according to Retnawati et al. (2017) and Sacristán (2005), this condition is considered normal because students are at an intermediate stage or stage of adaptation to something new. So, we need a way so that students can adapt to new conditions quickly so that they can follow the learning well. One suggestion is to improve the existing teaching materials that are easy to understand and can be done independently. Another suggestion is still relevant is to determine the areas that will be provided equally to all students so that classes can be unconditional and all learning objectives can be delivered and supervised properly.

During the study, researchers saw a good impression shown by students with learning follow to the end. However, after the random sampling for the interviews can be extracted other information related to the learning of students. Various images obtained by investigators. Although there were still students who preferred mathematics taught conventionally, in other words, it was not integrated with science and technology. But most students like mathematics learning that is integrated with science and technology because they think learning to be relaxed like a play. This result is in line with previous research which states that by integrating mathematics learning with science, the connection of knowledge to concepts across disciplines and their application to the real world becomes easier for students to understand (Honey et al. 2014; Johnson et al. 2015; Kelley & Knowles, 2016; Thibaut et al. 2018; Uğraş & Genç, 2018; Ültay & Ultay, 2020).

Regarding the situation of learning the result that a decision on the students to choose the field of learning, making students' confusion due to the STEM fields is nothing new for them and they do not know the capabilities of specialization in the field. The inability of students in participating in the learning does not necessarily make the students feel comfortable with the many activities undertaken. This is like what happened in the early USA using STEM learning, where STEM educators lack a cohesive understanding of STEM education but they could benefit from a STEM education conceptual framework (Kelley & Knowles, 2016). Through interviews also obtained results

of activities performed during the learning must always adjust, it is most closely related to the ability of teachers to understand the capabilities of their students.

Final Development of Teaching Material

Step development of integrated STEM instructional materials project-based learning is undertaken steps to develop teaching materials and validate the teaching materials that have been made. Steps taken to adapt the four-step development are as follows. (1) Research and information collecting, at this stage of research literature on teaching materials to be developed, gathering information related to STEM learning through observation and collection of teaching materials STEM prototype, then a field study to find out the characteristics of students where teaching materials will be implemented. (2) Step planning, at this stage of the formulation of the goals, to be achieved at each meeting and draft the initial design development of teaching materials. (3) Steps develop a preliminary form of product, at this stage of drafting a concept map activity, the integration of the STEM fields in every activity, until the drafting of the new teaching materials is completed. (4) Step preliminary field testing, the last step in this study, at this stage of validation by experts and tested in a small scope.

These steps are in line with the development stage which states that before a product is assessed by experts and tested on a large scale, a researcher needs to design a product so that the product is following the expected goals (Aryuntini et al. 2019; Muchsin et al. 2018; Thiagarajan et al. 1974). Besides, researchers also need to collect information from various sources (including collecting potential problems why this product needs to be developed) to formulate learning objectives and competencies so that researchers can design research products (Gall et al. 2007).

Table 3.

Consideration of the Validity of Advance Integrated STEM Instructional Materials Project-Based Learning

Activity	1	2	3	4	5	6	7	8	9
Judicial experts	1	1	1	0	1	1	1	1	1
Expert media	1	1	1	1	1	1	1	1	1
linguistic revision	R	-	R	R	-	-	-	-	-

Description: 0 = invalid, 1 = valid, R = Revision

The validity of advanced teaching materials related to the structure of the language of teaching materials has been prepared. Table 3 shows the results of consideration of the validity of the data advance STEM instructional materials project-based learning integrated by two experts, namely the judicial experts and media experts.

Then the results of consideration of the validity of the advance by two people validator statistically analysed using Q-Cochran. Test hypotheses formulated H_0: all experts/validator provide uniformity answers, and H1: not all experts/validator provide uniformity answers

Table 4.

Cochran Q-Test Results

N	Cochran's Q	df	Asymp.Sig.
9	1,000	1	0.317

Table 4 shows the data-Cochran Q test result data of validity of advance consideration of integrated STEM instructional materials project-based learning by two experts, namely the judicial experts and media experts. Retrieved Q-Cochran (x) of 1.00 is smaller than the value χ^2 = 3.84 (1.00 <3.84) in the table chi-square with α = 0.05 and df = 1, then H0 is accepted. In other words, all the experts give a uniform answer. Based on face validity, then the integrated STEM instructional materials developed project-based learning was valid.

The validity of the contents of teaching materials related to the linearity of the materials in any activity with indicators of achievement of competencies of teaching materials that have been prepared. Table 5 shows the results of consideration of the data content validity integrated project-based learning STEM instructional materials by two experts, namely the judicial experts and media experts.

Table 5.
Consideration of the Content Validity Integrated STEM Instructional Materials Project-Based Learning

Activity	1	2	3	4	5	6	7	8	9
Judicial experts	1	1	1	1	1	0	1	1	1
Expert media	1	1	1	1	1	1	1	1	1
Revised material	R	-	-	-	-	R	-	-	-

Description: 0 = invalid, 1 = valid, R = Revision

Then the results of consideration of the content validity by two validators analyzed using Q-Cochran statistics. Test hypotheses formulated as H0: all experts/validator provide uniformity answers, and H1: not all experts/validator provide uniformity answers

Table 6.
Cochran Q-Test Results

N	Cochran's Q	df	Asymp.Sig.
9	1,000	1	0.317

Table 6 shows the results of data-Cochran Q test result data of content validity considerations integrated project-based learning STEM instructional materials by two experts, namely the judicial experts and media experts. Retrieved Q-Cochran (x) of 1.00 is smaller than value = 3.84 (1.00 < 3.84) in the table chi-square with $\alpha = 0.05$ and df = 1, then H0 is accepted. In other words, all the experts give a uniform answer. Based on the validity of the content, the integrated STEM instructional materials developed project-based learning was valid. So that the developed products are mathematics teaching materials by using Project-Based Learning and integrating stem into categories that are feasible to be tested. In connection with this condition, the researcher took the next step, namely a limited-scale trial as suggested by Thiagarajan et al. (1974).

The construct validity relating to the validity of the test items that build the test can measure every aspect of thinking (Clark & Watson, 2015; Drost, 2011; Leary et al. 2013). The validity of construction related to the evaluation of motivation and interest in STEM learning integrated project-based learning. From the data assessment students' response to learning that uses integrated STEM instructional materials, project-based learning gained 0.92 percent to motivation and the percentage of interest of 0.61. Interpretation for motivation included in the category of very good validity and for interest included in the category of good validity.

Test the validity of the latter do is to test the validity of each item of evaluation at a meeting of unity (P-1) and the evaluation questions at the second meeting (P-2). Just as data is processed to determine the construct validity, the data used is the data obtained during the exercise test on a small sphere of one of the 36 students Junior High School in Bandung. Table 7 shows the results of the recapitulation of the correlation coefficient for each item of evaluation at the first meeting (P-1). The results of the analysis of the correlation coefficient produce categories of high validity for each point. It is based on a correlation coefficient of each item in the range 0.727 to 0,806 were categorized as high validity. The results of the second meeting presented in Table 8 which shows the results of the recapitulation of the correlation coefficient of each item evaluated in a second meeting (P-2)

Table 7.
Recapitulation of the Correlation Coefficient of Each Item Evaluation of P-1

Item No Problem	Correlation	Sign. Correlation
1	0.727	very Significant
2	0.727	very Significant
3	0.727	very Significant
4	0.757	very Significant
5	0,806	very Significant

Table 8 shows the correlation coefficient of each item evaluation of P-2. The results of the correlation coefficient analysis showed differences because of each item. Analysis of No. 1 included in the low category. This can happen because all students successfully answered question No. 1 correctly, but there are differences in outcomes for all students. So the question no one should be revised. As a matter of no 2 falls into the category of validity being and no 3 and 4 are included in a matter that has a higher category. These results indicate that in general the tests given to

students after using the developed teaching materials have a good influence on Mathematical Critical Thinking Skills. This result is in line with previous research which states that using problem-based learning can improve Mathematical Critical Thinking Skills (Afdareza et al. 2020; Aini et al. 2019; Mutakinati et al. 2018; Syafril et al. 2020; Yasin et al. 2019), the STEM context used in mathematics learning can also improve Mathematical Critical Thinking Skills (Susandi et al. 2018; Yasin et al. 2019, 2020).

Table 8.

Recapitulation of the Correlation Coefficient of Each Item Evaluation of P-2

Item No Problem	Correlation	Sign. Correlation
1	0.223	Not significant
2	0,622	Significant
3	0.732	very Significant
4	0.891	very Significant

Conclusion

As in other lessons, Instructional materials should have high flexibility and several instructions that are easy to understand (Jethro et al. 2012). The depth of the material, the arrangement of activities, and the amount of activity in a meeting to engineering product design results can be changed according to the analysis of the ability of the student by the teacher and the students' response to learning (Widodo, 2017). In this study, the development of teaching materials using the syntax PBL elaborated models of experts which was then integrated with STEM syntax. STEM approach used is an embedded approach and most liked STEM learning to record the same material given to all the activities and the many activities tailored to students' resistance to learning time. The main focus of this study is Preliminary field testing, not yet on a large trial. The results showed that the Integrated STEM instructional materials Project-Based Learning integrated finished passing pace of development, an examination by a judicial expert and expert media test to validate the instructional materials. The tests were obtained from the test results on Preliminary field testing of the 36 subjects who try to use the instructional materials in teaching. The results of the validation show that face validity and content validity of teaching materials is valid and feasible. Then the results of the construct validity included in the validity of the very good to excellent. Then the validity of each item on the evaluation showed high validity of the dominant values. It can be concluded from this study teaching materials are being developed valid and feasible for use in a limited scope or comprehensive study.

Recommendations

Suggestions for researchers to conduct large-scale trials (dissemination) so that the effectiveness of project-based learning materials is known by integrating STEM on critical thinking skills. It aims at the main objective of this research which is to get good teaching material products so that students' critical thinking skills can be achieved or improved. Also, this teaching material needs to be researched to see the effect of teaching material that has been developed on the ability of other students such as the ability to solve problems, communication skills, and creative abilities.

Suggestions for applicants such as teachers to use these teaching material products, especially to improve students' critical thinking skills. Also, researchers recommend that the use of research-based learning models can be integrated with STEM in the process of learning mathematics, including collaborating with e-learning or through blended learning.

Limitations of the Study

This development research was only carried out at the limited trial stage, so the student subjects used as participants in this study were only 36 students. Thus, this research can be generalized broadly. For that, it is necessary to research with a large number of research participants at the next stage (large trial).

Acknowledgment

The author would like to thank the Ministry of Research and Technology/National Research and Innovation Agency for providing funding for this research.

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