

The Mechanism Development of Digital Mathematics Material Study Based on STEM

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Abstract

Learning based on STEM is learning method combining four disciplines, namely; science, technology, manipulation, and mathematics. The purpose of the research was to create new product by improving digital study material. This research was Research and Development (R&D) by following Plomp development procedure. The trials was performed after the product was stated to be valid by the validator to examine the practicality, the effectiveness, and to know the teacher's and the students' perception to the developed study material. The subject to examine the practicality and to know the teacher's and the student's perception to the developed study material was the mathematics teachers the senior high school X grade students at SMAN 7 Denpasar year 2020-2021. The result of the research suggested that (1)The developed study material filled content validity aspect and construction validity since it was in accordance to the applied curriculum and the theory used as base of the study material development. While the construct validity was valued based on linkage among various components which constructed the product valued from density of material and media. (2) Mathematics study material based on STEM in the research filled practicality aspect since the positive responses from the students and the teachers were found during trial. (3) The developed study material was very effective to improve students' mathematics learning outcome.

Key Words: Development, Study Material, STEM, Digital Module.

Background

Learning is every effort involving teachers and students to share and manage information by hoping that the given knowledge can be useful for students and can be used as continuum learning base. Better changes are expected to achieve positive improvement signed with personal behavior changes for effective and efficient learning process (Sari et al., 2021; Gainau et al., 2022). The 21st century learning requires technology and information learning base to equalize melinial era requirement. The aim is that the students get used to live with skill needed in 21st century. The fact, the learning process is still far from the required learning in the 21st century. That phenomenon indicates that students can not adapt the recent education development. Because of this, it is urgent that the recent and conformable learning approach be performed. One of the efforts which must be performed by the government to develop education in Indonesia is by applying 2013 curriculum.

The study material can be modified based on the recent technology improvement oriented to digital era (As'ad et al., 2021; BP et al., 2021). The digital study material development is conformable with development and innovation in education field and in accordance with recent digital era. Therefore, the digital study material can be developed to increase students' study interest, and adapt the technology development as well (Dimiyati, & Mudjiono, 2015; Nursalimi, 2019).

The learning suited with the 21st century requirement is STEM. The learning based on STEM is one of the alternative solution for the competent learning in science, technology, design technique, and mathematics. Therefore, it is expected that the education can involve four knowledge disciplines (Milaturrahmah, N., Mardiyana, M., & Pramudya, I, 2017).

The learning based on STEM combines four knowledge disciplines, namely: science, technology, technique/manipulation, and mathematics. (1) *Science*, is knowledge about nature representing natural law related to physics, chemistry, biology, fact application, principle, concept and convection related to knowledge. (2) *Technology*, is skill or system used to manage communities, organization, knowledge or it can be meant as product of science and technique reality. (3) *Engineering*, the knowledge of technique by applying the concept of science and mathematics and technology tools to solve problems. (4) *Mathematics* is knowledge related to quantity, space, and number which needs logical argumentation. By learning based on STEM, the learning process will be more useful so the mathematics learning outcome can be improved (Torlaxson, T, 2014).

The result of interview and observation showed that the school have provided handout. However, the contents of the handout have not been suitable with 21st century learning which expect the students to have competence in science, technology, engineering, and mathematics. In addition, the applied study material still applied conventional approach and less interesting.

STEM-based mathematics learning is believed to be able to improve student learning outcomes That idea is very conformable with the research done by Seri et al, (2018) entitled *The development of science teaching materials based on STEM to increase science literacy ability of elementary school students* (Sari, N., Syarif Sumantri, M., & G Bachtiar, I, 2018). That research showed that (1) The study material based on STEM was classified valid to increase academic literacy ability (2) The study material based on STEM had high practicality value by giving easeness of the usage and material comprehension. (3) The

user of study material based on STEM gave the effectivity in increasing skill. The STEM learning involved the process of critical, analytic, and collaborate thinking. Therefore, STEM is combination involving four knowledge disciplines, namely: science, technology, technique/manipulation, and mathematics involving the process of critical, analytical, and collaboration of thinking. STEM learning involves five stages in the application in the class, namely: observation, new idea, innovation, creativity, and society (Pangesti, K. I., Yulianti, D., & Sugianto, 2017).

Study material has order design and sequence to explain the achieved instructional purpose and student learning motivation. Generally, students can study independently because the study material is systematic and complete. The existence of the study material has very useful impact, namely: (1) create the learning process become more interesting, (2) give opportunity for students to study independently and minimize dependency of the teacher presence. (3) And give easeness for the students in learning competence which must be comprehended (Pribadi, B. A., & Putri, D. A. padmo, 2019).

The study material development is applied the study material which will be performed. Because of this, the characteristics analysis related to students's situation, school and environment potency, availability of learning resources, and other supports must be performed. The developed study material is module. Module is a study material arranged systematically. It contains set of planned learning experience involving the content, the material, and the method to achieve the established indicator to increase student learning quality (Rahdiyanta, D, 2016).

As the development of information and communication technology runs, the study material is formulated in digital form. The combination of information technology and communication with such study material is called digital study material. Digital study material can be applied at anywhere since it is practical study material. Digital study material can be saved in long time and it can be developed based on the need and the purpose concept.

The aims of the research are: (1) To know the characteristics of mathematics study material based on STEM for senior high school X grade students in functional material, valid, practical, and efficient. (2) To describe the teachers' and the students' perception to digital mathematics study material based on STEM

Method

The research applied *Research and Development* (R&D), by applying Plomp development procedure. The research and development aimed to create new product by development process. The product which will be developed is digital study material. The kind of the developed study material is module.

There was the most important part of the research is to examine the product to the subject of the research. The activity was performed to describe the validity, the practicality, and the effectiveness of the developed study material. The trials were performed after the product was stated valid by the validator. The first stage, the product was examined for limited group to examine the practicality and the effectiveness. In addition, the trials were performed to know the teachers' and the students' perception to the developed study material. The validity Aspect was used to achieve the data which stated the validity of the content and the developed study material media (Rochmad, 2012).

The subjects which were used to examine practicality and to know the teachers' and the students' perception to the developed study material were the mathematics teachers and the X grade students of SMA Negeri 7 Denpasar, year 2020-2021. Sedangkan subjek untuk uji efektivitas dari bahan ajar yang dikembangkan adalah siswa kelas X SMA Negeri 7 Denpasar.

The researcher used development research instrument involving the validity, the practicality, and the effective aspects. In addition, the researcher aimed to know the teachers' and the students' perception to the developed study material. The research instrument used in the research were questionnaire and test. There were two questionnaires for validity aspects, namely: expert in material and media. In addition, there were two questionnaires for the teachers' and the students' responses. Both of the questionnaires above were used to get the data which stated the practicality of the developed study material. The instrument used to measure the effectiveness of the research was test. The teachers' perception were obtained from the comment given for the study material found in the teachers' response questionnaires. Whereas, the students' perception were obtained from the comment for the study material found in the students' response questionnaires.

Formative evaluation was performed in limited trials and site trials 1. Whereas, the summative evaluation performed in site trials 2 was used to revise draft 4. The result of draft 4 revision was called final product with valid, practical, and effective quality. After that, draft 1 was validated by three experts in material and three experts in media. The experts were appointed based on consideration related to the relevance of their knowledge and experience. The aspects validated by the experts involved: (1) The appropriateness of the valued content were the suitability of the material with KD, the material accuracy, learning material supports, and the current material; (2) The appropriateness of the valued presentation were presentation technique, presentation support, learning presentation, and presentation completeness; (3) The language evaluations were simple, communicative, dialogic and interactive, the suitability with the level of the student development, the continuance and cohesiveness of thought, terminology usage, and symbol or icon; (4) The valued learning was learning characteristics based on STEM.

The Research Result

Implementation stages were performed three times, namely:
Limited Trials.

This trials involved five students and a mathematics teacher of SMA Negeri 7 Denpasar. The focus of the trials was to get the description of developed study material performance. Formative evaluation was performed in this stage by using evaluation technique such as: questionnaire, observation, and learning outcome test. The result was used to revise draft 2. The result of this activity was called draft 3.

Tabel 1. The Result of Students' and The Teachers' Response Questionnaires

Aspects	Student Average	Teacher Average
Apperance	0.733	0.767
Material Presentation	0.767	0.733
Adventage	0.800	0.767
Total Average	0.767	0.756

The average of mathematics study material based on STEM and based on the students' response questionnaires was at 0.767 and the teachers' response was at 0.757. Those scores were converted suited with Guilford value aspect (Guilford, J.P., 1956), so the average of the students' response questionnaires was in range at $0.60 < X^- \leq 0.80$. That figure showed that the sudy material applied in the limited trials was classified good and practical in learning process.

Tabel 2 The Student Learning Outcome Test Recapitulation

The Result	The Result of The Student Limited Site Trials	The Result of Site Trials 1	The Result of Site Trials 2.
The Number of Students' Complete Value	4	33	35
The Number of Students' Incomplete Value	2	4	3
The Percentage of Classical completeness	66.67 %	89.19 %	92.11 %

Of eight students involving limited trials, only one students did not fill KKM value. The percentage of classical completeness was at 66.67% in the range $p > 80\%$ with good qualification. Based on conversion table in accordance with stipulated Guilford guidance (Guilford, J.P., 1956) the study material applied in limited trials was effective to apply in learning. Therefore, the students' value was complete.

The Site Trials 1.

The trials involved 37 students and mathematics teachers at SMA Negeri 7 Denpasar. The focus of the research was to increase the product quality. The result of the research was used to revise draft 3. The revision result of the activity was called draft 4.

Tabel 3. The Result of The Students' and The Teachers' Response Questionary

Aspects	Student Average	Teacher Average
Appearance	0.867	0.833
Material Presentation	0.877	0.867
Advantage	0.900	0.833
Total Average	0.878	0.844

The average of mathematics study material outcome based on STEM and suited with the students' response questionnaire was at 0.878 and the teachers' response was at 0.848. The score was converted in accordance with Guilford value aspects (Guilford, J.P., 1956) Therefore, the average of the students' response questionnaires was in the range $X^- > 0.80$. The number showed that the study material applied in the site trials 1 was classified very good and practical in learning process.

The average of mathematics study material outcome based on STEM and suited with the teachers' response questionnaires was at 0.844. It was in the range $X^- > 0.80$. That figure showed that the study material applied in the limited tials was classified very good and practical in learning process.

The average of mathematics study material outcome based on STEM and in accordance with observation was at 0.878. The average of observation was in the range $X^- > 0.80$. That figure showed that the study material applied in the site trials 1 was categorized very good and practical in learning process. Here are the result of the discussion during learning process.

Of 37 students involving in the site trials 1, only four students did not fill KKM value. The percentage of classical completeness was at 89.19% in the range $p > 80\%$ with very good qualification. Based on the conversion table in accordance with Guilford guidance (Guilford, J.P., 1956), the study material applied in the site trials 1 was effective to apply in the learning, so the students' value became complete.

Site Trials 2

The site trials 2 was used to revise draft 4. The result revision of draft 4 was called final product with valid, practical, and effective quality. The trials involved 38 students and the teachers of SMA Negeri 7 Denpasar. The trials focused to obtain final product. The trials involved semi summative test by applying several techniques such as: questionnaire, observation, and learning outcome test. The result of the trials was used to revise draft 4. The result of that activity was called final product.

Table 4. The Result of The Students' Response Questionnaires

Aspects	Student Average	Teacher Average
Apperance	0.900	0.833
Material Presentation	0.892	0.892
Advantage	0.867	0.900
Total Average	0.886	0.854

The average of mathematics study material based on STEM and in accordance with the students' response questionnaires was at 0.886 and the teachers' response was at 0.854. That score was converted in accordance with Guilford value aspect (Guilford, J.P., 1956) so the average of the students' response questionnaires was in the range $X^- > 0.80$. That figure showed that the study material applied in the site trials 2 was categorized very good and practical in the learning process.

Of 38 students involving in the site trials 2, only three students did not fill KKM value. The percentage of classical completeness was at 92.11% in the range $p > 80$ with very good classification. The study material applied in the site trials 2 was effective in the learning process so the students' value became complete.

The Analysis and The Discussion of The Research Result

1. The Analysis of The Study Material Validity

The study material validity in the research was seen based on the content validity and the construct validity. The average of validity result obtained from the material experts was at 0.859. The study material from the material experts was in in the range score > 0.7 For that reason, the developed study material was stated valid by the material experts and the average of the validity from media experts was at 0.838.

The validity of the study material was caused by several factors, namely: (1) The developed study material was in accordance with validity measurement aspects which filled the aspects of content and construct validities. (2) The study material developed in the research created the characteristics of mathematics study material based on STEM. (3) The developed study material was in accordance with the characteristics of mathematics learning based on STEM. (4) The developed study material was in accordance with the content appropriateness aspect such as: the material suitability with KD, the material accuracy, the study material support, the current material. The aspect of presentation appropriateness such as: presentation technique, presentation support, learning presentation, presentation completeness and language value aspect such as: simple, communicative, dialogis and interactive, the suitability with the students' development level, the continuance of cohesiveness of thought, the terminology usage, symbol or icon. The aspect of learning evaluation such as: characteristics of mathematics based on STEM. And the principle of mathematics learning based on STEM.

2. The Analisis of the Practicality of Teaching Material

The practicality measurement of the developed mathematics study material based on STEM was valued from the performance in the site. The performance involved how far the teachers and the students could apply the product well to achieve the learning. The aspect of the valued practicality criterias were: appearance aspect, material presentation aspect, and usage aspect. The data related to the practicality of the developed study material practicality were obtained from the observation result of learning performance the teachers' response questionnaires and the students' response questionnaires in every the end of trials.

The result of observation during limited trials showed the average at 0.780. The score was converted in accordance to Guilford value aspect (Guilford, J.P., 1956) so the observation average was in the range $0.60 < X^- \leq 0.80$. The range showed that the study material applied in limited trials was classified good and practical classification in the learning process. During limited trials, the mathematics teachers did not find problem applying mathematics based on STEM to the students. The site trials 1 showed that the average score of observation result got increase at 0.820. The observation average was in the range $X^- > 0.80$. It meant that the study material applied in the site trials 1 was categorized very good and practical classification in the learning process.

The site trials 2 also got increase in the score. The result average of mathematics study material based on STEM oriented to HOTS questions based on observation was at 0.867. The score converted in accordance with Guilford value aspect so the observation average was in the range $X^- > 0.80$. It indicated that the study material applied in the site trials 2 belonged to be very good and practical in the learning process. Based on the result of observation performed in the site trials 1 and 2, the application of the study material did not find problem at all. Therefore, the teachers applied the study material practically in the learning process. The result average of mathematics study material based on STEM and based on the students' response questionnaires in the limited

trials was 0.767. The score was converted in accordance with Guilford value aspect so the students' response questionnaires was in the range $0.60 < X^- \leq 0.80$. It meant that the study material applied in the limited trials belonged to be good and practical classification in the learning process.

The result average of mathematics study material based on STEM, based on the students' response questionnaires was at 0.767. The score was converted in accordance with Guilford value aspect (Guilford, J.P., 1956) so the average of the students' response questionnaires was in the range $X^- > 0.80$. It indicated that the study material applied in the site trials 1 belonged to be very good and practical classification in the learning process.

The result average of mathematics study material based on STEM, based on the teachers' response questionnaires was at 0.767. The average the teachers's response questionnaires was in the range $0.60 < X^- \leq 0.80$. It indicated that the study material applied in the limited trials belonged to be good and practical classification in the learning process. The site trials 1 got increase in the result average of mathematics study material evaluation based on STEM, based on the teachers' response questionnaires was at 0.844. The average of the teachers' response questionnaires was in the range $X^- > 0.80$. It indicated that the study material applied in the limited trials was categorized as very good and practical classification in the learning process.

The increase in the result average of mathematics study material evaluation based on STEM, based on the teachers' response questionnaires was also found in the site trials 2. It was at 0.854. The score was converted in accordance with Guilford appraisal aspect (Guilford, J.P., 1956) so the teachers' response questionnaires was in the range $X^- > 0.80$. It indicated that the study material applied in the site trials 2 was stated to be very good and practical classification in the learning process.

3. The Analysis of Study Material Effectiveness

Of six students who involved in limited trials, only two students did not fill KKM value. The percentage of classical completeness was at 66.67% in the range $p > 80$ with good classification. Of 36 students who involved in the site trials 1, only four students did not fill KKM value. The percentage of classical completeness was at 89.14% in the range $p > 80$ with very good classification. Based on the stipulated conversion table, the applied study material in the site trials 1 was very effective in learning process. Therefore, the students' was complete.

Of 38 students involved in the site trials 2 only three students did not fill KKM value. The presentage of classical completeness was at 92.11% in the range $p > 80$ with very high classification. Based on the stipulated conversion, the study material applied in site trials 2 was very effective to apply in learning so the students' value was complete.

Discussion

The research was successful to develop mathematics material study based on STEM for senior high school X grade students in functional material. The characteristics of mathematics study material was based on valid, practical, and effective STEM, namely: (1) The application of STEM context in the beginning of the learning; (2) The study material guided the students to develop vertical instruments (Chart, Model, and Scheme) which was discussed in the group; (3) The study material guided the students to use the students' work and to construct it; (4) The questions used as discussion material could stimulate interactivities online or offline; (5) Mathematics study material based on STEM was developed in digital module so the students could study independently at anytime and anywhere; (6) The final aim was formulated clearly; (7) The learning material was formulated into small or specific units so it could ease the complete learning process; (8) The examples and illustrations which supported clear description of learning material were available; (9) There was competent evaluation instrument which was used to measure or evaluate the grade of the functional material comprehension; (10) The summary of learning material was available; (11) There was answer key of competence evaluation.

The developed study material filled the content appropriateness aspects such as: material suitability with KD, material accuracy, learning material support, recent material. Mathematics study material based on STEM in the research was stated that the study material filled practical aspects since there were positive responses obtained from the students and the teachers during the trial. The observation result indicated that the students and the teachers did not find significant difficulty during the learning process. The students felt happy when following mathematics learning process. It was caused by several matters, namely: (1) The mathematics material was related to STEM chosen by the students; (2) The digital module could be used at anywhere and anytime without bringing printed books to anywhere; (3) The competence evaluation contained answer key which was available in online or offline learning process. Because of this, the students choose freely based on their comfort in learning process. It could be done in many times until they found the right answer.

The developed study material in the research was stated to be effective if the research could achieve required target, namely to improve learning output in functional material. The functional learning result is the result achieved by the students used as success proof in applying the developed study material. The success was valued from the students' comprehensions to learning concept and the students' ability in solving problems related to functional material taught and measured with description test. The test was given to the students every the end of the trial.

Conclusion

The research was successful to develop mathematics study material based on STEM as valid, practice, and effective material study for the X grade of S Senior high school students and the teachers.

1. The characteristics of mathematics material study based on developed STEM were: (1) The application of STEM context was performed in very beginning of the study; (2) The study material led the students to develop vertical instrument (Chart, Model, and Scheme) which were discussed in group; (3) The study material which guided the students to use the students' work and to construct it; (4) There were discussed questions which could stimulate interactivities in online or offline; (5) The material study based on STEM was developed in digital modul form so the students could study independently at anytime and anywhere; (6) The final aim of the study material was formulated very clearly; (7) There was competence evaluation

- instrument which was used to measure or evaluate the level of the material usage competence; (8) There was study material summary; (9) There was the answer key.
- The characters of mathematics material study material based on STEM were (1) The STEM context was performed in every beginning of the study; (2) The study guided the students to develop vertical instrument that could be discussed in the group; (3) The study material guided the students to use the students' work and to construct it; (4) There were discussed questions which could stimulated the students' interactivities online or offline; (5) There was linkage between functional material and mathematics material or STEM study material.
 - The developed study material filled content validity and construction validity aspects because it was suited with the applied curriculum and suited with the applied theory which was used as base in the study material development. While, construction validity was measured based on the linkage between some components which constructed the product valued from the comprehension of material and media.
 - Mathematics study material based on STEM in the research filled practicality aspect since there were positive responses from the students and the teachers during the trials.
 - The developed study material was very effective in improvement of the students' mathematics learning outcome. The outcome could be seen from every trials performed by several students who obtained complete value than the students who obtained incomplete value.
 - The students of senior high school stated that the developed study material was very helpful for them to study mathematics independently.
 - The teachers of mathematics senior high school were helped very much because of the existence of the developed study material.

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