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Development of Open Ended Based Mathematics E-Modules to Enhance Students' Critical Thinking Ability

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ABSTRACT

In the current era of globalization, students' critical thinking skills are still low, so teaching materials that support learning are needed. In the learning process, educators have not developed teaching materials that are following technological advances, and existing teaching materials use more routine questions so that students only accept and follow the flow and rules rather than experimenting and finding answers or solutions on their own. Therefore, this study aims to produce an open-ended based mathematics e-module product on a system of two-variable linear equations for class VIII students of junior high school, to determine the feasibility of the product in terms of valid, practical, and effectiveness, to determine the increase in students' critical thinking skills after using e-module. This is development research with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). This research was conducted at a Public Middle School in Purworejo for the 2021/2022 academic year. The data collection technique in this study was carried out through questionnaires and tests. The instruments used in this study were validation sheets, questionnaires, and tests. Data analysis techniques use validity, practicality, and effectiveness tests. The results of this study are open-ended-based mathematics e-modules to improve students' critical thinking skills. The product test results showed that the e-module validity score obtained a percentage of 80% from material experts and 82.5% from media experts. The results of the practicality test of the e-module obtained a percentage of 78% from the limited test and a percentage of 74% from the wide test. The results of the effectiveness of open-ended-based mathematics e-module products, namely the N-Gain test, obtained 0.6 in the medium category. The data shows that the e-module developed in this study is categorized as feasible. Students' critical thinking skills after using open-ended-based mathematics e-modules have increased.
Keywords : Critical Thinking, Open-Ended, Development, E-Module.

ABSTRAK

Di era globalisasi pada saat ini, kemampuan berpikir kritis siswa masih rendah sehingga diperlukan bahan ajar yang mendukung pembelajaran. Dalam proses pembelajaran, pendidik belum mengembangkan bahan ajar yang sesuai dengan kemajuan teknologi dan bahan ajar yang ada lebih banyak menggunakan soal-soal rutin sehingga peserta didik hanya menerima dan mengikuri alur dan aturan daripada melakukan eksperimen dan menemukan jawaban atau solusinya sendiri. Maka dari itu, penelitian ini bertujuan untuk menghasilkan produk e-modul matematika berbasis open ended pada materi sistem persamaan linear dua variabel untuk siswa kelas VIII SMP, mengetahui kelayakan produk dari segi valid, praktis dan efektif, untuk mengetahui peningkatan kemampuan berpikir kritis siswa setelah menggunakan e-modul. Penelitian ini merupakan penelitian pengembangan dengan model ADDIE (Analysis, Design, Development, Implementation, and

Evaluation). Penelitian ini dilaksanakan di SMP Negeri di Purworejo tahun pelajaran 2021/ 2022. Teknik pengumpulan data pada penelitian ini dilakukan dengan angket, dan tes. Instrumen yang digunakan pada penelitian ini adalah lembar validasi, angket dan tes. Teknik analisis data menggunakan uji kevalidan, kepraktisan, dan keefektifan. Hasil penelitian ini adalah e-modul matematika berbasis open ended untuk meningkatkan kemampuan berpikir kritis siswa. Hasil uji produk menunjukan skor kevalidan e-modul diperoleh presentase sebesar 80% dari ahli materi dan diperoleh presentase sebesar 82,5% dari ahli media. Hasil uji kepraktisan e-modul diperoleh presentase sebesar 78% dari uji terbatas dan diperoleh presentase sebesar 74% dari uji luas. Hasil dari keefektifan produk e-modul matematika berbasis open ended yaitu dengan uji N-Gain diperoleh 0,6 dengan kategori sedang. Data tersebut menunjukan bahwa e-modul yang dikembangkan dalam penelitian ini dikategorikan layak. Kemampuan berpikir kritis siswa setelah menggunakan e-modul matematika berbasis open ended mengalami peningkatan.
Kata kunci: Berpikir Kritis, Open Ended, Pengembangan, E-Modul.

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PRELIMINARY

Mathematics is a very important subject to study because it is available at almost every level of education (Huzaimah & Amelia, 2021; Siregar, 2017). This is due to mathematics is an activity of human life, meaning that mathematics is used in daily life activities, for example in buying and selling, savings and loan activities, and others (Gazali, 2016; Ramdani, 2006; Wahyudi et al., 2018). Mathematics also teaches patterns of critical, analytical, and systematic thinking in problem-solving both in mathematics lessons and in its application (Kurniasih, 2017; Novtiar & Aripin, 2017). Critical thinking is one of the abilities that must be possessed by humans in the current era of globalization (Haryani, 2011; Juhji & Suardi, 2018; Pertiwi, 2018). There are several definitions of critical thinking.

Critical thinking is a process of using rational and reflective thinking skills that aim to make decisions about what to believe or do (Mahmuzah, 2015; Setiana & Purwoko, 2020; Kusumaningrum et al., 2020; Kuncoro et al., 2021). Because of that, the decisions taken affect the final results achieved. Critical thinking ability itself is part of the reasoning. This is in line with the opinion of Krulik and Rudnick, that "reasoning includes basic thinking, critical thinking, and creative thinking" (Sulianto, 2008). Thus, it can be concluded that critical thinking is an important part of learning mathematics. Therefore, learning mathematics should be directed not only at mastering and understanding concepts

but also at improving students' thinking abilities and skills, especially critical thinking skills (Setiana, Purwoko, et al., 2021).

The findings show that Indonesian students' critical thinking skills are still far below the international average score. Indonesia is in the 39th position out of 43 countries with a score of 386 out of the international average score of 500 (TIMSS, 2011). It means that Indonesian students are still weak to solve non-routine questions, prove problem-solving that requires reasoning and find relationships between the data provided. On this basis, students' critical thinking skills need to be improved by compiling teaching materials that are appropriate to the material to be delivered. One of the teaching materials that can be used is the module. Modules are a set of printed teaching materials that are presented systematically (Elvarita et al., 2020; Tania & Susilowibowo, 2017). This aims to facilitate teachers and students in learning activities. The module can make it easier for students to understand the material independently. Based on the results of interviews conducted by researchers, in the mathematics subject the media used was print-based media such as math textbooks, worksheets, and modules. The teacher has never developed an electronic module, to be more precise, has not taken advantage of today's technological advances.

E-modules are teaching materials that are systematically designed based on a certain curriculum and packaged in certain learning units, which are displayed using electronic devices such as computers or Android, where each learning activity in them is connected with a link as navigation which makes students more interactive with programs. The use of teaching materials that utilize the role of electronic technology will have a positive impact on students' use of gadgets (Fitriansyah, 2016). Like developing e-modules using the kvisoft flipbook maker application. The kvisoft flipbook maker application is an application that will help in the learning process because this application is not fixated on just writing but can include motion animation, video, and audio which can make interactive learning media interesting so that learning is not monotonous. (Ningsih & Mahyuddin, 2022). So e-modules using the kvisoft flipbook maker application can be accessed offline and don't have to incur a lot of costs because they are in the form of soft files (Hidayatullah & Rakhmawati, 2016).

The development of interactive teaching materials must also pay attention to material and practice questions to avoid teacher-centered learning. If the teacher does not improvise and develop in the learning process, the teaching materials or textbooks will be more dominant in the learning. The impact is on the activeness of students in the learning process. Students will be more passive in accepting and following the flow and rules than

doing experiments and finding answers or solutions on their own as part of the experience. The solution that can be chosen to overcome this problem is to use an open-ended approach. Open-ended learning begins when presenting a question to students where the problem has more than one method or answer (Faridah et al., 2016; Utami et al., 2020). Based on this background, the researchers conducted research with the objectives of (1) developing open-ended mathematics e-module teaching materials on the subject matter of two-variable linear equation systems for junior high school students; (2) finding out the feasibility of open-ended based math e-module products to improve students' critical thinking skills, and (3) find out the increase in students' critical thinking skills after being given open-ended based math e-modules.

METHODS

This research is development research that produces a product in the form of an open-ended-based mathematics e-module. This product has specifications to improve students' critical thinking skills. The product will be tested based on its effectiveness after field trials (Budiyono, 2017; Fannie, R., 2014). The development design used in this study uses the ADDIE model. The ADDIE model consists of 4 stages of development, namely: (1) Analysis; (2) Design; (3) Development; (4) Implementation; and (5) Evaluation (Mulyatiningsih, 2014). This research was conducted at SMP Negeri 2 Purworejo grade VIII in the odd semester of the 2021/2022 academic year.

The instruments used in this study were: (1) Validation sheets for validity testing, which were submitted to two experts, that is a media expert and a material expert, to obtain comments, suggestions, or criticisms as a basis for product revisions; (2) Response Questionnaire to test practicality, which is given to students as research subjects to determine the extent to which students respond to the media being developed. (3) Written tests, namely the pre-test and post-test, which are prepared based on indicators of critical thinking skills, namely FRISCO (Focus, Reason, Inference, Situation, Clarity, and Overview) for the effectiveness test, to measure the extent to which the level of students' critical thinking skills before and after using the e-module (Sunaryo, 2014). The stages of this development research are presented in Figure 1.

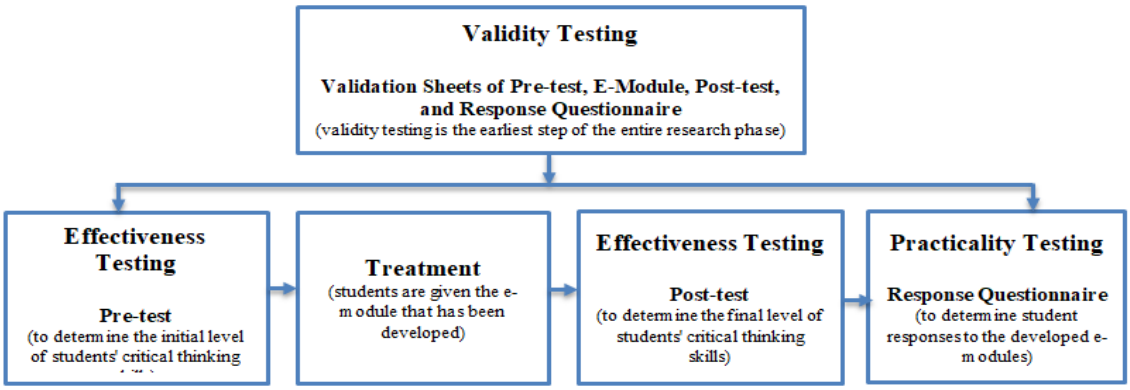

Figure 1. The Stages Of The Development Research

Validation sheets and questionnaires were prepared using a Likert scale. According to (Sugiyono, 2015), the Likert scale is a scale used to develop instruments to measure the design of a product. The data obtained from the validity and practicality test results are then expressed in the form of a percentage. The percentage results are then converted into 5 criteria. Product validity is expressed in very valid, valid, valid enough, invalid, and invalid criteria. Score intervals and product validity criteria are shown in Table 1.

Table 1. Product Validity Criteria

Score Intervals	Criteria
81% - 100%	Very Valid
61% - 80%	Valid
41% - 60%	Valid Enough
21% - 40%	Invalid
0% - 20%	Invalid

While the practicality of the product is stated in the criteria of very practical, practical, quite practical, less practical, or impractical. The score intervals and product practicality criteria are shown in Table 2.

Table 2. Product Practicality Criteria

Score Intervals	Criteria
81% - 100%	Very Practical
61% - 80%	Practical
41% - 60%	Pretty Practical
21% - 40%	Less Practical
0% - 20%	Impractical

To be able to determine the interval scores as presented in Table 1 and Table 2, calculations were made using the formula:

Interval = 100/max score (Likert)

Interval = 100/5

= 20

So, the interval for each category is 20

The effectiveness of the developed product can be seen from the pretest and posttest scores. The results of the pre-test and post-test are used to measure the level of improvement in critical thinking skills before and after using the developed e-module. Pre-test and post-test data were analyzed using the N-gain test (Nugraha & Muhtadi, 2015).

The n-gain score aims to determine the effectiveness of using a particular method or treatment in one group pretest-posttest design research (experimental design or pre-experimental design) or research using a control group (quasi-experiment or true experiment). The N-gain score test is carried out by calculating the difference between the pre-test values (tests before the application of certain treatments). By calculating the difference between pretest and posttest scores or the gain score, we can find out whether the use of a particular method can be said to be effective or not. The n-gain score test can be used when there is a significant difference between the average post-test score of the experimental group and the post-test score of the control group through the independent sample t-test.

RESULTS AND DISCUSSION

A. Analysis Stage

The analysis phase used is an analysis of media needs, material analysis, analysis of student characteristics, and analysis of literature studies. A media needs analysis was carried out by interviewing mathematics teachers. The results of the needs analysis concluded that (1) the curriculum used in schools is the 2013 curriculum; (2) teaching materials used by teachers and students for learning activities are textbooks and student worksheets from the government; (3) there are no teaching materials, especially mathematics that utilizes technology, attract students, and help students study independently at home, and (4) the teaching materials used have not encouraged students' critical thinking skills.

Material analysis is carried out by examining and identifying learning materials to be used in the development process so that the learning materials used are relevant to the e-module to be developed. In addition, at the material analysis stage, an analysis of learning objectives is also carried out to determine the competencies that students need to have. The results of the material analysis concluded that there are still many students who do not understand the material of the two-variable linear equation system so media is needed that can be used for independent learning. Analysis of student characteristics is carried out so that the e-modules developed is by the stages of student development.

Apart from that, an analysis of literature studies was also carried out, to examine the suitability between the abilities you want to improve and the learning media you want to develop (Puspita et al., 2022). From the results of media and material analysis, it can be concluded that teaching materials are needed in the form of open-ended based mathematics e-modules that can explore students' critical thinking skills in the matter of a system of two-variable linear equations. The development of this e-module is expected to help teachers and students to create independent learning and to build students' critical thinking skills. In addition, it is expected that all teachers and students can master and use technology when conducting learning (Arigiyati et al., 2021).

B. Design Stage

At the design stage, the initial preparation of e-modules, learning materials, and research instruments was carried out. The instruments were prepared in the form of validation sheets for material experts and media experts as well as questionnaires for students and test instruments. The material taken is material on a system of two-variable linear equations. Validation sheets were given to material experts and media experts, to find out the validity of the products being developed, questionnaires were given to students to find out the practicality of the products that had been developed, and tests were given to students to find out the effectiveness of the products that had been developed.

C. Development Stage

At this stage, the researcher begins to make e-module parts with the Canva application, from the cover to the bibliography. The e-module design is then consulted with the media and material validators to produce a product that is ready to be tested on students in a valid category.

Figure 2. Display of the developed e-module

The validation process aims to find out whether the instrument being developed can measure what you want to research (Setiana, Kusumaningrum, et al., 2021). To get a quality product, this e-module goes through a process of material validation and media validation. Material validation was carried out by mathematics education lecturers and mathematics education teachers at SMP N 2 Purworejo while media validation was carried out by mathematics education lecturers. The results of the validator assessment analysis are presented in Table 3.

Table 3. The results of the analysis of the validator's assessment

Validators	Percentage	Criteria
Material Validators 1	75%	Valid
Material Validators 2	80%	Valid
Media Validators	82.5%	Very Valid

Table 1 shows that the assessment results of the material validators and media validators are in the valid and very valid categories (with a little revision). Thus, the developed product is suitable for use in the field. In addition to providing an assessment, the validator also provides input on the initial draft of the product. As for suggestions or input from the validator, that is, it is better not to include the brand of an item in the sample questions, simply by mentioning packaged drinks or other examples. In addition, in student activity 2, the presentation of the questions should be made in tabular form so that they are more detailed and the questions are made the same so that students can conclude the material for themselves. After being revised according to input from validators, the final draft of the e-module is ready for use in the field on small-scale and large-scale trials.

D. Implementation Stage

At this stage, researchers conducted field trials consisting of small-scale trials and large-scale trials. Small-scale trials were carried out at SMP Negeri 4 Purworejo class VIII G, which at this stage involved only 6 students and large-scale trials were carried out in class VIII A involving 30 students. The large-scale trial was conducted on the next day for 2 meetings after the small-scale trial which was conducted in 1 meeting. Field trials were conducted to find out the practicality of the developed open-ended-based mathematics e-modules. The practicality assessment is analyzed through student responses and through suggestions for the e-modules that have been developed. The results of field trials on a small scale are shown in Table 4.

Table 4. Small-Scale Trial Results

Aspect	Percentage	Criteria
Ease of Use	82%	Very Practical
Time efficiency	71%	Practical
Benefit	82%	Very Practical
Average	78%	Practical

In Table 4, it can be seen that the developed e-module is in the very practical category in terms of ease of use and usability, and is in the practical category in terms of time efficiency. Overall, the developed open-ended-based math e-modules can be said to be practical with an average percentage of 78%. While the results of field trials on a large scale are shown in Table 5.

Table 5. Results of Student Scale Tests on Broad Tests

Aspect	Percentage	Criteria
Ease of Use	73%	Practical
Time efficiency	75%	Practical
Benefit	75%	Practical
Average	74%	Practical

Based on Table 5, it can be concluded that the developed e-module can be used in the field. The results of large-scale field trials show that e-module products are practical to use in learning in terms of ease of use, time efficiency, and benefits.

At the implementation stage, effectiveness was also tested using the pre-test and post-test and analyzed using the N-gain test and t-test. Based on the results of the analysis, the N-Gain score was 0.6 in the medium criteria, which means that the e-module is effective for use in the field. Then an analysis of the pre-test and post-test results was carried out using the t-test and obtained t_{count} = 0.5032 and t_{table} = 1.99897 so that it can be seen that $t_{count} < t_{table}$, which means that there is a significant difference in value between the pre-test and post-test. It can be seen that the score obtained is positive, meaning that the post-test score is higher than the pre-test score. This means that there is an increase in critical thinking skills in students. It can be concluded that after using the open-ended-based mathematics e-module, students' critical thinking skills experienced a significant increase.

E. Evaluation Stage

After implementing the open-ended-based math e-module draft on a small and large scale, it was concluded that the e-module that had been developed was valid, practical, and effective for use in learning. This open-ended-based mathematics e-module product can be used in learning to improve students' critical thinking skills which contain FRISCO

indicators: Focus, Reason, Inference, Situation, Clarity, and Overview. Focus means that students answer according to the context of the problem; Reason means that students can provide reasons related to relevant facts or evidence at each step in concluding, Interence means that students can draw appropriate conclusions based on the identification process at the completion step. The situation means that students can collect relevant information and use relevant mathematical concepts to answer questions; Clarity means that students can provide clarity on symbols or things that are not yet clear; and Overview means that students have re-checked their work from start to finish. This research is in line with research conducted by Maryam et al., (2019) which resulted in the conclusion that mathematics modules with an open-ended approach can improve students' critical thinking skills with a percentage of student completeness of 68%. Miftakhudin et al. (2019) research result state that mathematics e-modules with an open-ended approach can improve students' critical thinking skills, so that as a whole the stages of this development can produce products in the form of e-modules that have a potential effect on increasing the critical thinking skills of junior high school students. Koth et al., (2021) reveal that students gaining knowledge via a content-expert-designed e-module performed similarly to those participating in a traditional lecture, indicating that e-learning could serve as a valuable resource for professional students. Furthermore, e-modules can inspire critical thinking applications of foundational knowledge, required by CODA in dental professional student education and training. Shalihah et al., (2022) found that the development of open-ended-based mathematics e-modules can be applied to other learning approaches and also with other materials so that students can gain new experiences and knowledge.

CONCLUSION

Based on the results of the research and analysis carried out, it can be concluded that an e-module based open-ended has been produced to improve critical thinking skills in the matter of a system of two-variable linear equations for grade VIII junior high school students that is valid, practical, and effective. The validity of the product is seen from the results of the validators' assessment, both media validators, and material validators. Overall, this product is valid in terms of the suitability of the material, presentation of the material, and media design. Product practicality can be seen from the results of product testing in the field on a small and large scale. Student assessment of the product developed is practical for use in learning in terms of ease of use, time efficiency, and usefulness. This shows that the open-ended-based e-module is easy to use, the time allotted is sufficient for

students to answer questions, and can support students' critical thinking skills. Product effectiveness can be seen from the significant increase in post-test results compared to pre-test results.

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