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Development of e-Module with Integrative Problem-Based Learning Approach to Improve Students' Algebraic Reasoning

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Abstrak

Penelitian ini bertujuan untuk menghasilkan e-modul yang valid, praktis, dan menarik serta dapat meningkatkan penalaran aljabar peserta didik. Jenis penelitian ini yaitu penelitian pengembangan dengan model pengembangan ADDIE. Teknik pengumpulan data meliputi observasi, wawancara, angket, tes, dan dokumentasi. Teknik analisis data dilakukan secara kuantitatif dan kualitatif. Teknik analisis data kuantitatif terdiri atas analisis statistik, uji-t, uji N-gain, dan statistik deskriptif. Teknik analisis data kualitatif terdiri atas hasil validasi, wawancara, dan respon peserta didik. Hasil penelitian ini menunjukkan bahwa: 1) proses pengembangan e-modul dengan pendekatan *problem based learning integratif* untuk meningkatkan penalaran aljabar peserta didik dilakukan dengan cara, yaitu: a) analisis kebutuhan dan kondisi peserta didik; b) menentukan capaian pembelajaran dan materi, mendesain e-modul, dan membuat instrumen penilaian; c) Validasi e-modul oleh 5 ahli dengan nilai rata-rata persentase 84,1% dan berada dalam kategori valid. Validasi kepraktisan oleh dua praktisi dengan rata-rata persentase 89,1% dan berada dalam kategori praktis; d) Uji coba e-modul pada kelompok kecil yang dilanjutkan uji lapangan kelompok besar pada 30 peserta didik kelas VIII dengan rata-rata persentase 82,3% dan e) Evaluasi penggunaan e-modul secara sumatif yang menunjukkan e-modul layak untuk digunakan dalam pembelajaran. 2) Peningkatan penalaran aljabar sebesar 0,185 setelah peserta didik menggunakan e-modul.

Kata Kunci: e-Modul, Problem Based Learning, Matematika terintegrasi Islam, Penalaran aljabar

Abstract

This study aims to produce e-modules that are valid, practical, and attractive and can improve students' algebraic reasoning. This type of research is development research with the ADDIE development model. Data collection techniques include observation, interviews, questionnaires, tests, and documentation. Data analysis techniques are quantitative and qualitative. Quantitative data analysis techniques include statistical analysis, t-test, N-gain test, and descriptive statistics. Qualitative data analysis techniques include validation results, interviews, and student responses. The results of this study showed that: 1) the process of developing e-modules with an integrative problem-based learning approach to improve students' algebraic reasoning is carried out in a way, namely: a) analyzing the needs and conditions of students; b) determining learning outcomes and materials, designing e-modules, and making assessment instruments; c) Validation of e-modules by five experts with an average percentage value of 84.1% and is in the valid category. Practicality validation by two practitioners with an average percentage of 89.1% and is in the practical category; d) e-module trials in small groups followed by extensive group field tests on 30 grade VIII students with an average percentage of 82.3% and e) Evaluation of the use of e-modules summatively which shows e-modules are suitable for use in learning. 2) An increase in algebraic reasoning of 0.185 after students use a math learning e-module.

Keywords: e-Module; Problem-Based Learning; Islamic integrated mathematics; Algebraic reasoning

Introduction

According to Samo [1], algebra is an integral part of mathematics that generalizes arithmetic through symbols, letters, and sure signs. The importance of algebra is stated in the Regulation of the Minister of Education and Culture Number 21 of 2016 concerning Content Standards, which states that students can use reasoning related to patterns and properties, manipulate mathematics to generalize, compile evidence, or explain ideas from mathematical statements [2]. Algebra mastery underlies mastery of other mathematical concepts, such as functions, equations, inequalities, and linear systems [3]. One of the abilities needed in learning algebra is algebraic reasoning.

According to Andriani [4], algebraic reasoning is one of the abilities used to solve problems related to generalizing numbers, quantities, relations, and functions through investigation and conclusions to prove their truth. In solving algebraic problems, students must be able to reason to solve problems so that students believe that mathematics can be understood, proven, and evaluated. [5]. This is supported by the National Council of Teachers of Mathematics (NCTM), which explains that algebraic reasoning is focused on mathematics curricula worldwide [6], [7]. Thus, algebraic reasoning in mathematics is a fundamental element of mathematical thinking.

Based on the results of research by Basir & Aminudin [8], so far in mathematics learning, less attention is paid to the development of algebraic reasoning. Hence, students' algebraic reasoning is still low. In addition, the Trends in International Mathematics and Science Study (TIMSS) results in 2011 showed that the average percentage in the reasoning and algebra domains was the lowest among the four domains at 17% and 22%, respectively [9]. The TIMSS survey results also show the weakness of students in working on problems that require algebraic reasoning skills [10], [11]. In addition, the research results by Absorin and Sugiman (2018) showed that 27 students, or 70.37%, had weak algebraic reasoning skills in answering TIMSS reasoning model questions. Research results show that students' algebraic reasoning is still low.

To achieve the condition of students with sound algebraic reasoning, it is necessary to apply a learning or teaching material that supports students' algebraic reasoning, as in the research of Sadikin & Herutomo [13] and Sermatan, Fahinu, & Zamsir [14] who developed algebraic reasoning using the Jigsaw type Cooperative learning model and Problem-Based Learning (PBL). Both studies gave positive results on students' algebraic reasoning. In addition, Fitrianna, Priatna, & Dahlan [15] developed e-book-based interactive teaching materials to train algebraic reasoning. The results of the study had a significant effect on students' algebraic reasoning. These studies show that students' algebraic reasoning can be improved through interactive teaching materials in learning mathematics.

One form of teaching material is e-modules. E-Modules are independent learning media in electronic form that aim to realize the learning competencies to be achieved [16], [17]. The importance of developing an e-module for students can be proven from the many researchers in developing e-modules in learning mathematics, for example e-modules based on Learning Content Development System [18], Open Ended-based e-modules [19], Android-based e-modules [20], e-modules using Mobile Learning with PBL approach [21], and PBL-based interactive e-modules [22]. The results showed that interactive e-modules can be developed to achieve the desired competencies in mathematics learning. The success of the previous research triggered this research to create an interactive e-module with an integrated problem-based learning approach.

Development of e-modules with an integrative problem-based learning approach, namely the development of electronic modules that present mathematical materials and problems combined with Islamic values [23]. The Islamic-integrated PBL approach makes the initial learning stage difficult for students in Islamic contexts [24]. Providing problems aims to enable students to construct mathematical concepts independently [25], [26]. What is meant by integrative is integrating mathematics with spiritual values sourced from the Al-Quran, hadith, Islamic history, fiqh, and other Islamic references [27], [28],

[29]. This integration does not mean only including Islamic-based spiritual values but connecting, integrating, and applying them in the syntax of problem-based learning.

On the other hand, some studies use a problem-based learning approach in Islamic integrated mathematics learning. Syazali [30] revealed that the module he developed had met the valid and practical criteria with the PBL approach integrated with Islamic values. Alghar [24] and Ulum [31] show the design and implementation of mathematics learning integrated with Islamic values with a problem-based learning approach. Darmawan, Syahputra, & Fauzi [32] explained that there is a significant influence between Islamic-oriented problem-based learning models on students' mathematical spatial abilities. This series of studies shows that the problem-based learning approach integrated with Islam positively impacts mathematics learning.

Based on the previously described, it is necessary to develop e-modules that can improve students' algebraic reasoning. Therefore, this research aims to develop e-modules with an integrative problem-based learning approach to improve students' algebraic reasoning.

Methods and Data

This research uses a type of Research and Development research with the ADDIE model, which consists of five stages, including analysis, design, development, implementation, and evaluation [33], [34]. (1) Analysis stage. At this stage, researchers made initial observations and literature studies to discover the initial learning problems. (2) Design stage. Researchers design e-modules with an Integrative PBL approach at this stage to improve students' algebraic reasoning. Some steps in this stage include determining learning outcomes, material design, e-module design, and compiling research instruments.

(3) Development Stage. At this stage, researchers develop e-modules based on a previously made design, which includes e-module development, expert validation, and product revision; (4) Implementation Stage. At this stage, limited trials (small groups) and field tests (large groups) were carried out. The limited trial involved eight students of class VIII MTs Surya Buana Malang. The field test involved 30 students of class VIII C and VIII D MTs Surya Buana Malang as the experimental class. (5) Evaluation stage. At this stage, product assessment is carried out. The assessment results are used to provide feedback on the developed e-modules. In addition, researchers also made the last revision to perfect the e-module Used.

The instruments used in this development research consist of validation sheets, practicality instruments in the form of teacher practicality questionnaires, attractiveness instruments in the form of student response questionnaires, and test instruments to measure students' algebraic reasoning. Quantitative data analysis techniques are carried out through (1) Validity test, practicality, and attractiveness of e-Modules by calculating the feasibility presentation derived from the questionnaire scores. The percentage of feasibility is used with the following formula.

$$\text{Percentage of eligibility} = \frac{\sum \text{score obtained}}{\text{score criteria}} \times 100\%$$

The percentage data obtained is then measured by the validity, practicality, and attractiveness qualifications presented in Table 1.

Table 1 Qualification of validity, practicality, and attractiveness of e-Modules

Percentage (%)	Qualification	Category
<29	Invalid/not practical/not attractive	Revision
30-49	Less valid/less practical/less attractive	Revision
50-69	Reasonably valid/practical/attractive enough	Minor revision
70-89	Valid/practical/attractive	No revision needed

90-100	Very valid/very practical/very attractive	No revision needed

(2) Paired sample t-test to determine whether there is a significant difference between the average pre-test and post-test scores. The hypothesis in the t-test (Paired Sample t-test) is: H0: There is no significant difference in improving students' algebraic reasoning before and after using the e-module. H1: There is a significant difference in improving students' algebraic reasoning before and after using the e-module. (3) The N-Gain test aims to determine the magnitude of the increase in students' algebraic reasoning ability after using the developed product. The formula used in the N-Gain Test is

$$N - Gain = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{m}_{\text{ideal}}} - S_{\text{pre}}}$$

Table 2 shows the results of acquiring the average value of N-gain, qualified according to the gain criteria adapted from Hake (1999).

Table 2 Interpretation of N-Gain Average Score

N-Gain $\langle g \rangle$	**Criteria**
$\langle g \rangle \geq 0.7$	High
$0.3 \leq \langle g \rangle < 0.7$	Medium
$\langle g \rangle < 0.3$	Low

Qualitative data analysis techniques are carried out through (1) analysis of student test results after using the developed product. (2) In-depth interviews with students related to the test results given. (3) Asking for student responses after using the product.

Result and Discussion

The ADDIE development model was used for product research and development, and the following is a description of the results of each stage of development.

Analysis Stage

The analysis stage aims to collect and review data on problems and needs in the mathematics learning process. Analysis activities include needs analysis and analysis of learner conditions. Needs analysis is conducted to discover the issues in the field, including learning and teaching materials, SPLDV material, algebraic reasoning aspects, and the need for e-modules. The needs analysis was conducted by giving questionnaires and interviews to students and mathematics teachers. The needs analysis results show no teaching materials with an integrative PBL approach to improve students' algebraic reasoning at MTs Surya Buana Malang.

The conditions of students were analyzed using algebraic reasoning tests on 30 class VIII C MTs Surya Buana students in Malang City. The results showed that students' algebraic reasoning was still lacking. Based on the needs analysis results and students' conditions, teaching materials that can improve students' algebraic reasoning must be developed.

The results at the analysis stage obtained from interviews and questionnaires show that teachers have never used a problem-based learning approach in teaching in class. This indicates that teachers always teach with traditional models that are considered more efficient in time and easy to do. Lessani, Yunus, & Bakar [35] and Raja & Khan [36] explain that teachers tend to use the lecture method because it is easy to use and does not require much preparation. In addition, the analysis results show that the teaching materials used are only printed modules or textbooks. The absence of interactive modules limits students' learning resources. This can also reduce students' interest in learning mathematics because using learning resources is not eye-catching [17], [20].

Design Stage

At the design stage, the e-module is developed based on PBL learning syntax. Class management, group research, problem orientation, and analysis and evaluation of proposed solutions are all part of the PBL learning process. The syntax of this e-module also includes activities that aim to improve students' algebraic reasoning according to the indicators of algebraic reasoning.

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The results at the design stage consist of making learning outcomes, materials, e-modules, and research instruments. The learning design refers to the 2013 curriculum with the material presented, namely the system of linear equations of two variables (SPLDV). The e-module design was created using Canva. As explained by Tambunan [37] and Tanjung & Faiza [38], using canva provides convenience through a system integrated with electronic devices and presents an interactive display. In addition, the design stage also produced validation and practicality questionnaires and algebraic reasoning test sheets.

Development Stage

The development stage includes the development of the designed E-Module, the preparation of mathematical critical thinking instruments, and the E-Module assessment. This stage aims to create and modify the E-Module until it is ready to be tested. E-Modules that are developed are then verified by experts using instruments that have been developed previously. Expert validation includes validation of material experts, Islamic experts, language experts, learning experts, and design experts. Validation activities are needed to obtain validation from experts on the developed e-Modules.

Based on the results of the validation activities, it is obtained that all aspects have valid and very valid qualifications with a percentage of feasibility, namely aspects of design feasibility on e-modules 94.2% with a very valid category, aspects of language feasibility on e-modules 91.7% with a very valid category, aspects of material feasibility on e-modules 75% with a valid category, aspects of learning feasibility on e-modules 82.5% with a valid category, and aspects of Islamic/religious feasibility on e-modules 77.3% with a valid category so that the average feasibility of the e-module validation results is 84.1% with the valid category.

A practicality test was conducted on the developed e-module in the next stage. In the practicality test, three aspects were assessed: the display aspect of the e-module, the material presentation aspect of the e-module, and the benefit aspect of using the e-module. The practicality validators consisted of two mathematics teachers, with the validation results being that all elements have a category with a percentage of feasibility, namely the display aspect of the e-module has a feasibility of 88.9% with a practical category, the aspect of presenting material on the use of e-modules has a feasibility of 93.1% with a convenient category, and the element of the benefits of using e-modules has a feasibility of 85.7% with a practical category. So, the average results of the validation of e-modules by practitioners are 89.1% with a helpful category. Practical e-modules will make it easier for users to use and help them understand the electronic content of the module, improving student learning outcomes.

The results at the development stage in e-module validation show several aspects of validity. The Islamic aspect is 77.3% with a valid category, the language aspect is 91.7% with a very valid category, the material aspect is 75% with a valid category, the learning aspect is 82.5% with a valid category, and the design aspect is 94.2% with a very valid category. The practicality of e-modules was assessed by two practitioners, with an average percentage value of 89.1% in the practical category. The results of product validation show that the e-module can be tested. As described by Basir & Aminudin [8], Rochsun & Agustin [16], and Syazali [30], after the product is valid on the aspects tested, the product has the feasibility to be applied in the field. In addition, the valid validation results align with Basir & Aminudin [8], who developed an electronic module with a feasibility of 92%, and Fitrianna [15] with a validity feasibility of 83.5%.

Implementation Stage

A field test (large group) was carried out in the implementation stage. The subjects taken were 30 students in classes VIII C and VIII D. In this field test (large group), students were given a learning e-module that each expert and validator had validated. A student response questionnaire is provided after the students have studied the e-module. Based on the results of the field test analysis, it was obtained that all aspects had an average with valid, practical, and exciting categories. The percentage of each element, namely the validity aspect of the e-module, has a feasibility of 84.1%, the practicality aspect has a feasibility of 89.1%, and the attractiveness aspect has a feasibility of 82.3%. This shows that the learning e-modules developed are valid, practical, and attractive.

Furthermore, these 30 students were given algebraic reasoning post-test questions. The pretest and post-test results were then carried out, along with the t-test and N-gain test. It is shown that the results of the T-test are related to the pretest and post-test values. The following presents the results of the T-test data based on the pretest and post-test scores of students' algebraic reasoning using SPSS in Table 3.

Table 3 T-Test Results of Pretest and Posttest Values of Algebraic Reasoning

Paired Samples Test

					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pair	PRETEST	-	8.440	1.541	-12.085	- 5.782		29	.000
1	POSTTEST	8.9333					5.797		

Based on the results of the T-test, the pretest and post-test scores of students' algebraic reasoning are said to have significant differences. Then, the N-Gain test will be carried out because the t-test is explicitly used only to determine the significance value of increasing students' algebraic reasoning. To find out the magnitude and criteria for improving students' algebraic reasoning skills, the N-gain test calculation is used as follows:

$$N - Gain\ \langle g \rangle = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{m}_{\text{ideal}}} - S_{\text{pre}}} = \frac{48 - 36.13}{100 - 36.13} = 0.185$$

The results of the acquisition of the average value of N-gain obtained 0.185. Based on the qualification of the N-gain criteria presented in Table 2, it can be seen that the increase in students' algebraic reasoning using the developed e-module has increased. However, the growth that occurred was still not optimal.

Based on the results of the implementation stage in the small group test with eight students, it shows that all aspects of the developed module have valid, practical, and attractive categories, with each percentage, namely the display aspect of the e-module 83.9%, the content aspect of the e-module 86.1%, and the use aspect of the e-module 81.2%. The results of the extensive group test with 30 students obtained aspects of e-module validity with a percentage of 84.1%, aspects of practicality at 89.1%, and attractiveness at 82.3%. This shows that the learning e-modules were developed to meet the valid, practical, and exciting aspects. These results are in line with the research of Basir & Aminudin [8], Herlina & Abidin [17], and Syazali [30], which show that valid results in each aspect in small groups and large groups are parameters that products developed are suitable for use.

Evaluation Stage

The research results are at the evaluation stage, where an assessment of the development of e-modules in learning is provided. Evaluation is carried out in two forms, namely formative tests and summative tests. Formative tests are carried out during the learning activities presented in the e-module, while summative tests are carried out after the learning activities. Summative tests measure the final competencies or learning objectives to be achieved. The test results are used as an evaluation to provide feedback on the e-modules developed.

Furthermore, analysis of evaluation and data collection techniques in the form of questionnaires, tests, and interviews obtained results that have been described at the implementation stage, which show e-modules with an integrative problem-based learning approach can improve algebraic reasoning of Madrasah Tsanawiyah class VIII students. This is shown in the e-module development process, which has been declared valid, practical, and attractive. There is an increase in the algebraic reasoning of students before and after being given e-modules. Thus, e-modules with an integrative problem-based learning approach can improve algebraic reasoning of students can be used.

The evaluation stage with the formative test is carried out during the learning activities presented in the e-module. Meanwhile, evaluation in the form of summative tests is carried out after the learning activities as a whole. Summative tests measure the final competencies or learning objectives to be achieved [34]. The summative test results on the T-test showed that the e-module was in a category that was feasible to use. In addition, the N-Gain test results showed an increase in algebraic reasoning of 0.185. Both results show that the developed e-module can significantly positively change students' algebraic reasoning. In line with Turnip & Karyono [39], products that have provided significant positive changes are suitable for mass production and are used as guidelines in developing e-module teaching materials. In addition, the positive results are also in line with the research of Herdianto [21] and Junantari [22], who developed teaching materials in the form of modules and student worksheets to improve students' mathematical abilities.

The Improvement of Student’s Algebraic Reasoning

Based on the data analysis results, it is found that there is a difference in algebraic reasoning before and after being given an e-module. This can be seen in the pretest and posttest results of students' algebraic reasoning. The results of the pretest and posttest of algebraic reasoning of 30 students were that 25 students experienced an increase and five students experienced a decrease. In addition, the validity test results related to the pretest and posttest scores of algebraic reasoning of 30 students are said to be valid and reliable.

Then, the pretest and posttest reasoning results based on the t-test results show significant differences. In addition, the results of the N-gain test with an average N-gain obtained of 0.185 indicate an increase in students' algebraic reasoning using the e-module developed meets low criteria. This is in line with the research of [14], which states that the problem-based learning model can improve students' algebraic reasoning skills. In addition, Fitrianna [15] also explained that electronic book products are adequate for training students' algebraic reasoning skills. Meanwhile, Yekti & Perdana [40] and Jalal & Afandi [41] explained that their products in the form of Student Worksheets were able to improve students' mathematical reasoning in the field of Algebra. The results of these various studies align with the results of the researcher's research, which shows an increase in students' algebraic reasoning after using e-modules with an integrative problem-based learning approach to improve algebraic reasoning.

Although the paired t-test indicated a statistically significant improvement in algebraic reasoning, the N-Gain score of 0.185 falls into the “low” category according to Hake’s criteria. Several pedagogical and cognitive factors may influence this. First, the short implementation period may not have been sufficient for students to internalize the syntax of integrative PBL [42], [43]. Second, higher-order cognitive skills, such as algebraic reasoning, require sustained and structured practice [44], [45]. A single intervention resulted in a significant yet relatively low improvement. These findings suggest that although the electronic module meets standards of validity, practicality, and appeal, extended implementation and student familiarization with algebraic generalization and justification strategies are still necessary.

Limitation

This study has methodological limitations. The effectiveness of the module was evaluated using a single-group pretest-posttest design involving 30 students. Although this design provides evidence of improved learning, it is susceptible to bias, for example the testing effect or external teaching factors, since there is no control group for comparison. Therefore, the observed improvement in algebraic reasoning must be interpreted with caution. Future research should employ a quasi-experimental design with a control group to examine the specific impact of the electronic module and validate claims of effectiveness.

Conclusion

Based on the research that has been done, several things can be concluded, namely (1) the process of developing e-modules with an integrative problem-based learning approach to improve students' algebraic reasoning is carried out using the ADDIE development research model. The stages carried out by referring to the ADDIE model are a) the analysis stage, which includes needs analysis and analysis of students' conditions; b) the design stage by determining learning outcomes and materials, designing e-modules, and compiling assessment instruments; c) development stage which includes e-module validation with an average percentage value of 84.1% and is in the valid category and practicality validation with an average percentage value of 89.1% and is in the practical category; d) Implementation stage by testing e-modules in small groups and large groups which resulted in an average percentage of 82.3%, so that the e-modules developed were in the valid, practical, and attractive categories; and e) Evaluation stage, by conducting a summative evaluation of the use of e-modules, which shows that they are suitable for use in learning. (2) There is an increase in students' algebraic reasoning after using the e-module, with an increase of 0.185 based on the N-Gain test results.

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