AKSIOMA: Jurnal Program Studi Pendidikan Matematika
Volume 13, No. 3, 2024, 921-935

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

MATH EDUCATIONAL GAME TO ENHANCE JUNIOR HIGH SCHOOL STUDENTS' ALGEBRAIC THINKING

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Received 09 July 2024; Received in revised form 12 August 2024; Accepted 02 September 2024

Abstract

Students in the 21st century require training in solving real-world problems involving algebraic thinking through the use of technology in order to adapt effectively to their environment. This study aims to develop a math education application on algebra material that is valid, practical and effective for improving algebraic thinking skills. This type of research is development research with the ADDIE model. The research instruments employed in this study were: 1) expert validity, 2) an algebra test sheet, and 3) a questionnaire to gather students' reactions to the developed educational game. Validity comprised game validity and content validity, aiming to obtain a valid and usable mathematics educational game. The data was analysed descriptively through the results of the educational game validity sheet. Meanwhile, the effectiveness of the educational game was observed through the results of the algebra ability test using a t-test. Furthermore, through the student response questionnaire, the researcher was able to ascertain the practicality of using the mathematics educational game. The results of this study indicate that the results of expert validation: (1) Feasible based on the validation results of media experts and material experts; (2) Practical based on student response questionnaires with excellent criteria; and (3) Effective where the average learning outcomes of the experimental class are better than the control class, a classical completeness of 81.14% was attained, positively correlated with learning interest, which in turn contributed to learning outcomes of 72.7%.

Keywords: game; math; algebraic thinking.

Abstrak

Abad 21 mengharuskan siswa untuk terlatih dalam memecahkan masalah kehidupan nyata yang berkaitan dengan pemikiran aljabar menggunakan teknologi agar mampu beradaptasi dengan baik dilingkungannya. Penelitian ini bertujuan untuk mengembangkan aplikasi pendidikan matematika pada materi aljabar yang valid, praktis dan efektif untuk meningkatkan kemampuan berpikir aljabar. Jenis penelitian ini adalah penelitian pengembangan dengan model ADDIE. Instrumen penelitian yang digunakan adalah: 1) validitas ahli, 2) lembar tes aljabar, 3) angket yang berisi reaksi siswa kepada game edukasi dikembangkan. Validitas terdiri dari validitas game edukasi dan validitas materi bertujuan untuk mendapatkan game edukasi matematika yang valid dan layak digunakan. Data tersebut dianalisis deskriptif melalui hasil lembar validitas game edukasi. Sedangkan, keefektifan game edukasi dilihat dari hasil tes kemampuan aljabar dengan menggunakan perhitungan uji-t. Selanjutnya, peneliti melalui angket respon siswa peneliti dapat mengetahui kepraktisan penggunaan game edukasi matematika. Hasil penelitian ini menunjukkan bahwa hasil validasi pakar: (1) Layak berdasarkan hasil validasi pakar media dan ahli material; (2) Praktis berdasarkan kuesioner respons siswa dengan kriteria unggulan; dan (3) Efektif dimana rata-rata hasil pembelajaran kelas eksperimen lebih baik dari kelas kontrol, persentase keuntasan klasikal adalah 81,14%, dan ada pengaruh positif minat belajar dengan hasil pembelajaran sebesar 72,7%.

***Kata kunci**: game; matematika; berpikir aljabar.*

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

INTRODUCTION

The integration of technology into education has a positive impact on the development of multi-dimensional 21st century skills and academic attainment (Yılmaz, 2021). It offers solutions to learning challenges A. Aslamiyah et al. (2019)], and use of the e-learning method has a positive influence on motivation, autonomy, participation, mathematical concepts (Moreno-Guerrero et al., 2020). Moreover, caution and education in how to use technology are needed, as any use not underpinned by effective and informed pedagogy can also lead to students feeling overwhelmed and disengaging from learning (Bedenlier et al., 2020). Law on Teachers and Lecturers no. 14 of 2005 requires teachers to have professional competence to master educational technology. Therefore, teachers' mastery of educational technology is key to quality teaching and learning.

Teachers' capacity to employ educational technology can be enhanced through training in the development of technology-based learning materials (Kristiawan & Muhaimin, 2019). Learning media conveys messages from teachers to students that can attract students' attention(Rachmavita, 2020) Furthermore, Learning media is a supporting factor for the success of the school teaching and learning process (Nursidik et al., 2017). In addition, educational technology can assist learners in boosting their achievement and interest in mathematics (Egara & Mosimege, 2024). Therefore, educational media can be one of the teaching tools which can help in learning activities and a catalyst for the improvement of the quality of students' thinking (Sumarwati et al., 2020).

Some students in junior high school experience difficulties in algebraic form material. Though, lgebra is a fundamental branch of mathematics that focuses on manipulating symbols to solve a wide range of mathematical problems(Maghfiroh et al., 2024). Algebra is about using symbols and following specific operations to solve problems. Developing algebraic thinking is a key mathematical skill that is valuable both inside and outside the classroom. Many of our activities require us to think critically using algebraic reasoning and symbolic representation to solve problems(Basir et al., 2022). Algebraic thinking refers to the skills and processes involved in learning algebra. It can be categorized into three main types of abilities: generating algebraic expressions, manipulating algebraic expressions, and understanding the overall structure of algebraic concepts.

Generational ability involves creating algebraic expressions and equations. Transformational ability focuses on manipulating these algebraic forms through actions like factoring, expanding, substituting, adding, multiplying polynomials, solving equations, simplifying expressions, and finding equivalent forms.Global-level meta abilities go beyond algebra problem-solving, using algebraic concepts as tools for solving various types of problems.

In addition, the teaching methods used still focus on the teacher and are still conventional. The activities carried out by students during math learning are only listening and tend to be passive so the learning felt by students is less fun and boring. The selection of interesting and interactive learning media greatly influences enjoyable learning activities

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

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(Qureshi et al., 2023). During learning, the media that teachers use are still limited in the form of material books and do not support fun learning activities. Learning media innovation is an effort that teachers can make to improve the quality of the mathematics learning process.

To enhance students' algebraic and critical thinking abilities, we need a specific learning approach. This approach should be designed to equip students with the skills to think critically and creatively about math problems. A student-centered learning model is ideal for this purpose. By actively engaging students in the learning process, we can foster the development of their algebraic thinking skills (Appah et al., 2020; Mohammad et al., 2023). Research related to the development of the importance of algebraic thinking, according to (Farida & Lukman Hakim, 2021), who said that the average student has difficulty in solving problems related to algebra. In addition, Agustyaningrum et al. (2020) dominant factors that cause students difficulties of abstract algebra learning in strong category consisting of students' attitudes towards abstract algebra, lack of prior knowledge, and inadequate teaching materials. Furthermore, difficulty is due to the lack of student knowledge related to algebraic material (Istikomah et al., 2020).

Furthermore, several educational game studies have been conducted, including animated videos as learning media has been conducted extensively, including the development of learning media for children with special needs (Barut & Dursun, 2022)and the development of Android-based learning media (Hidayat et al., 2023). However, despite the various studies conducted, there has been no research on developing Android in education to enhance algebraic thinking. Research conducted (Ervera Nur Arifah, 2019) found that the educational game “Bilomatika” is valid, practical, and effective for improving the understanding of grade 1 junior high school students on Number material. Research conducted (Abdullah et al., 2018) found that the educational game “Trigo Fun” is valid, effective, and practical to improve student learning outcomes in solving Trigonometry problems. Research conducted(Safitri et al., 2020) found that educational games with the context of Banten's local wisdom on matrix material were declared feasible, practical, and effective for use as learning media. The research shows that educational games are effective as learning media.

Therefore, This topic is both compelling and highly pertinent to contemporary research. Given the aforementioned problem, this study aims to develop mathematics learning videos that integrate contextualised traditional Indonesian games and digital technology. It is hoped that this will broaden our understanding of how technology can be combined with play, and that students will develop the skills necessary to solve real-world problems that require algebraic thinking.

METHODS

The type of research used in this study is research and development (R&D). The R&D model used is the ADDIE (analyze, design, develop, implement, and evaluate). The ADDIE development model is applied to create a dynamic number card application. The reason for choosing the ADDIE model is its educational philosophy that deliberate learning should be student-centred, inventive, authentic, and inspiring.

The ADDIE model is a five-phase technique. The first stage is analysis,

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

which aims to discover possible explanations for a performance disparity. The design phase follows to validate the expected performances and appropriate testing methodologies. The development phase's goal is to create and validate learning resources. The implementation phase is concerned with making the learning environment and engaging students. In contrast, the evaluation phase is concerned with assessing the quality of the instructional products and procedures before and after implementation. Then, in the following paragraphs, each aspect of this investigation is expounded on further.

The first step taken by the researchers was to collect information related to algebra ability. The first researcher observed students and interviewed the principal and the first-grade homeroom teacher. The questions asked were about the learning process in class, the learning media used, and students' number sense ability. After that, the researchers analyzed the curriculum, students' characteristics, and mathematics content learned by students.

The second step is designing. This stage has a vital role because at this stage the researchers begin to develop the product, including 1) Looking for various supporting reference sources related to educational applications and number sense for first-grade students, 2) Making a grid of instruments as a follow-up step from previous observations and interviews, 3) Planning the manufacture of media, namely educational application to match the competencies to be achieved in learning, 4) Designing educational application; 5) Design number cards as attractive as possible; 6) Look for various forms of application images related to number sense, and 7) Use the Adobe Animate to create an educational application.

The third phase is development, and the researchers conduct expert validation. Validation from the experts is helpful to find out whether the math educational application is feasible to be used in learning or not. With the help of experts, media improvement can be carried out appropriately. Expert validators for this study consist of three experts; two are researchers in mathematics education, and one is an experienced teacher in junior high school. The implementation stage involves implementing the media design developed in real situations (Cahyadi, 2019). As a further step from the development stage, at the implementation stage, the media has started to be tested on students. In small-group trials, more students were involved than during one-on-one trials. In a head-to-head trial, the media was evaluated by three students.

Meanwhile, small group trials were conducted on six students. During the one-on-one trial, the first researcher showed the application to the students, let them play with it, and then asked their opinions through interviews. Meanwhile, during the small group trial, students played the application in a small group. At the end of the meeting, the students were asked to fill out a questionnaire to know the product's practicality. All students could already read the questions, but the first researcher gave technical support to students who had difficulties understanding the questions.

The evaluation stage is the last step and aims to receive feedback from students as dynamic number card application users. At this stage, the evaluation used is formative. Formative evaluation is conducted at the end of

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

every face-to-face meeting. The small group test was conducted on six first-grade students. Tests were conducted to obtain more relevant data and corrections and suggestions regarding media products that had previously gone through several stages of revision. The researchers also conducted interviews with each student to see what the students' final response to using the dynamic number card application was.

RESULTS AND DISCUSSION

Based on the research and development of mobile apps to improve algebraic thinking skills that have been carried out, the following results are obtained.

Analyze Stage

The analysis stage is divided into two phases: performance and needs analysis. The following explains the steps of analysis.

a. Performance Analysis

Performance analysis was carried out by making observations at SMP NU 06 Sedungsuren. Based on the observations, information was obtained that students needed help with algebraic material, and the available learning resources, namely material books, still needed to be improved. In addition, the delivery of material still uses conventional learning methods, so students only listen and tend to be passive, which makes students less active in class. Therefore, a solution is needed to help students learn mathematics, especially algebraic material. One is the need for teaching media to involve students during learning. So, researchers develop exciting and innovative learning media in the form of math educational games with a contextual approach.

b. Need Analysis

1) Student Needs Analysis

Students' needs are analyzed by making observations to collect data. The observation results show that students need exciting and fun learning media that makes understanding the mathematics learning material easier.

2) Curriculum Analysis

Curriculum analysis was conducted to determine the school curriculum implemented as a reference for developing products. After making observations, it is known that the curriculum used at SMP NU 06 Kedungsuren is the 2013 curriculum.

3) Material Analysis

Based on the 2013 curriculum for class VII mathematics, one of the materials studied is algebraic forms.

Design Stage

The theme used in making the background has a rural feel where the user can control the movement of the character with the D-Pad button to explore the village while studying algebraic material. After all the materials were ready, the researcher created a scene in Adobe Animate CC 2018 (64bit) and set the layer size to landscape view. The researcher makes and inserts an Action Script in each Adobe Animate CC 2018 frame so that the product functions. Then, the researcher checks for errors in the Action Script. The product needs an Action Script or media content improvement if an error occurs. In contrast, if there is no error, it can be exported as an Android application with the Android Package Kit (APK) extension. One example of how this product design looks is the

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

material page. The material page contains dialogs that provide information to the user regarding algebraic form material. The material page design can be seen in Figure 1.

Figure 1. The Material Page View

Develop Stage

Development begins with expert validation. The expert validation phase is conducted to determine the feasibility of educational game products on algebraic materials and correct product weaknesses based on validation questionnaires of media experts and material experts. The material expert will show an assessment of the quality of the material's content. In contrast, the media expert will provide an assessment of the quality of the display and the media components.

Media expert validation is used to determine the feasibility of a product based on media aspects with 3 experts namely: Nurina Happy, M.Pd., a BNSP-certified expert instructor; Ali Shodiqin, M.Si., an instructor at Griya Konten Kreator, UPGRIS; and Fajar Noviardhi, S.Pd., a practitioner in Kendal district, Central Java.

The data analysis was conducted using the following methodology to determine the percentage of each aspect: cohesiveness, balance, letter or font, colour, and language. The results of the study were: The media is a viable tool for research when adapted to meet specific research goals. While some modifications are required to enhance its suitability, initial evaluations have been highly positive, with all scores surpassing the 85% threshold. For a general overview of the results of validation by media experts can be seen in Table1.

Table 1. Media Expert Validation Results

No.	Aspects	Score Validator			Score Max	Percentage Feasibility
		I	II	III		
1	Cohesiveness	14	13	12	45	86,67%
2	Balance	10	8	9	30	90,00%
3	Font	20	17	18	60	91,67%
4	Colour	20	17	17	60	90,00%
5	Language	10	9	9	30	93,33%
Total Score		74	64	65	225	90,22%

Media specialists had an average product feasibility percentage of Media specialists had an average product feasibility percentage of 90.22% in Table 2. Validation findings. Media experts believe that the criteria included in the mathematics educational game goods are worthwhile since, as indicated by the survey evaluation criteria table, 90.22% of the respondents fall into the very good category.

Media experts' opinions and recommendations are given as material to be taken into consideration for improving the product in the validation questionnaire. The following comments and suggestions from media experts can be seen in Table 2. The following is a

AKSIOMA: Jurnal Program Studi Pendidikan Matematika
Volume 13, No. 3, 2024, 921-935
ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

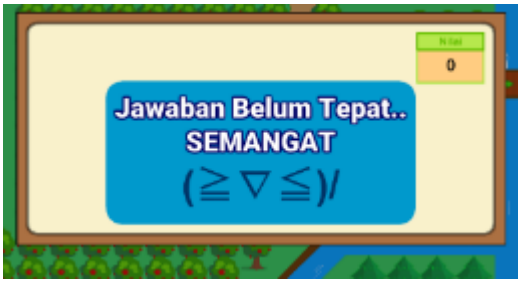
DOI: https://doi.org/10.24127/ajpm.v13i3.10778

media view of mathematical educational games before and after being revised based on media experts' advice, which can be seen in Table 3.

Table 2. Media Expert Repair Advice

No.	Media Expert	Repair Advice
1	Validator A	(1) Sound the first time the application is opened; (2) Feed back on offline evaluation is too loud and feed back for online evaluation is not there yet; (3) Clarified again the benefits of boxes that can be filled in answers but have no effect; (4) Check back the answer key some something is wrong; (5) There needs to be a close button on the snake ladder game; (6) The final part is less smooth that the game will end
2	Validator B	It's good and worth using
3	Validator C	It's good

Table 3. Revision In Learning Media

Before Revised	After revision
Feedback on evaluation is too harsh 	Feedback on evaluation is refined 
	Provides instructions after evaluation 
The boxes that can be filled in the answers have no effect 	The box is replaced with a button that has an effect 

AKSIOMA: Jurnal Program Studi Pendidikan Matematika
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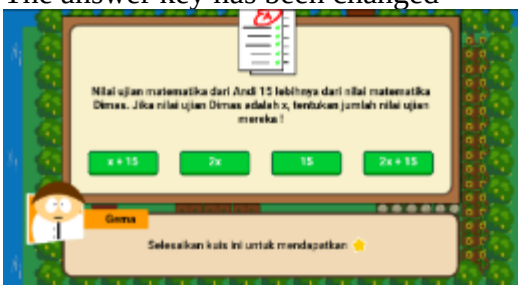
ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

Before Revised	After revision
Wrong answer key 	The answer key has been changed 
There is no close button yet on the snake ladder game 	There's already a close button on the snake ladder game 
The final part is less smooth 	The final part is made smooth 

The level of the product's validity based on the material aspect is determined by expert validation of the material.

Based on the expert assessment of the material, the data analysis was performed by calculating the percentage of each aspect broken down into three categories: content quality, learning quality, and contextual evaluation. Validation by three independent experts on the material revealed that, with minor revisions, the media content could be suitable for research purposes. Table 4 provides a broad summary of the validation results from media experts

Table 4. Material Expert Validation Results

No.	Aspect	Score Validator			Score Max	Percentage Feasibility
		I	II	III		
1	Content Quality	39	32	36	120	89,17%
2	Quality of Learning	25	24	21	75	93,33%
3	Contextual Assessment	40	33	36	120	90,83%
Total Score		104	89	93	315	90,73%

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

In Table 4. the results of the material expert validation showed that the average percentage of product feasibility by material aspect was 90.73%. The proportion of 90.73% on the very excellent criteria, as indicated by the questionnaire evaluation criteria table, indicates that the goods that incorporate mathematical educational games meet material experts' recommendations for inclusion.

The material expert validation questionnaire takes into account the media experts' provided opinions and ideas in order to make improvements to the product. The following are comments and suggestions from material experts that can be viewed in Table 5. The mathematical educational game materials before and after being revised based on the advice of experts the material can be seen in Table 6.

Table 5. Material Expert Repair Advice

No.	Media Expert	Repair Advice
1	Validator D	(1) There is a statement that has not been completed with a question sentence; (2) Completeness of the information: it is necessary to claim that the number of baskets is equal
2	Validator E	(1) Adjust the KKO to the indicators according to the revised Bloom Taxonomy; (2) Consistent the problems in the media with those in the LKPD
3	Validator F	Consistent the problems in the media with those in the LKPD

Table 6. Revisions In Game Material

Before Revised	After Revision
Statement does not yet include question sentences	The statement is equipped with a question sentence
	
Quiz no claims information yet	Quiz already on claims information
	

AKSIOMA: Jurnal Program Studi Pendidikan Matematika
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ISSN 2089-8703 (Print)
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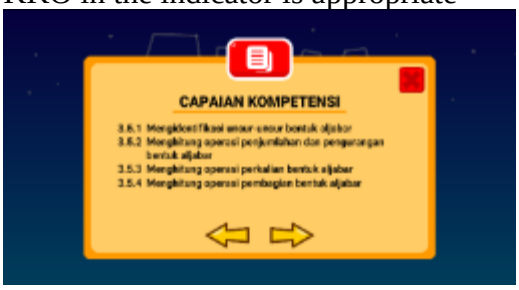
Before Revised	After Revision
KKO in the indicator does not correspond yet	KKO in the indicator is appropriate
	
Problems not consistent with LKPD	The problem is consistent with LKPD
	

Implementation Stage

Following suitability testing, field experiments are conducted on the learning medium. According to the findings of a field trial evaluation of the

The research results from several aspects were: content quality aspect, engineering quality aspect, and learning aspect The results showed that 85% of the 28 students surveyed considered the application to be practical. Student response questionnaire assessment results can be seen in Table 7.

Table 7. Student Response Questionnaire Assessment Results

No	Aspect	Total Score	Max Score	Practicality
1	Content Quality	365	420	86,90%
2	Engineering Quality	502	560	89,64%
3	Quality of Learning	346	420	82,38%
	Total Score	1213	1400	86,64%

Table 8 shows that the average percentage of product practicality based on student responses was 86.64%. Based on the scale conversion table, a rate of 86.64% was on excellent qualifications, so mathematical educational game products, including practical criteria, were used.

Evaluate

a. Individual Learning Completeness

Student learning outcomes are said to be individually complete if they achieve a score ≥ 70 in accordance with the KKM for mathematics subjects at SMP NU 06 Kedungsuren. Based on attachment 24, the individual learning completeness of the 28 experimental class students is 23 students have completed it and 5 students have not completed it, while for the 28 students in the control class, 15 students have completed it and 13 students have not completed it.

b. Completeness of Classical Learning

This test was used to determine whether or not student learning outcomes

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

DOI: https://doi.org/10.24127/ajpm.v13i3.10778

had reached classical completeness. A t-test was employed to ascertain the classical completeness of student learning, with a minimum completeness value of 70 as shown in Table 8.

Tabel 8. Results of t-test Classical Learning Completeness

	Test Value = 70					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Experiment	2.557	27	.016	3.41214	.6746	6.1497

In Table 8 reveals that the significance value (2-tailed) is less than 0.05, indicating that the mean score of the experimental group on the algebraic thinking test differs significantly from 70 and is, in fact, 73.41. Consequently, the experimental group can be considered to have achieved the classical criterion of success.

c. Comparison of mean scores on an algebraic thinking test

This study aims to investigate the effectiveness of contextualised mathematics educational games in enhancing student achievement. Specifically, this test was employed to ascertain whether there is a statistically significant difference in the performance of students who were exposed to this instructional approach compared to those who were not. As a prerequisite to this analysis, the assumptions of normality and homogeneity of variance were examined, and the results are tabulated in Tables 9 and 10.

Tabel 9. Test of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
Score	Experiment	.155	28	.084	.968	28	.517
	Control	.150	28	.106	.954	28	.251

Table 9 shows that the data of classes that get learning using educational games and classes that do not get learning using educational games come from normally distributed data. This can be seen in the Sig. value which each shows> 0.05.

Tabel 10. Test of Homogeneity

		Levene Statistic	df1	df2	Sig.
Score	Based on Mean	.017	1	54	.896
	Based on Median	.019	1	54	.891
	Based on Median and with adjusted df	.019	1	53.253	.891
	Based on trimmed mean	.019	1	54	.891

Table 10 demonstrates that the groups which utilised educational games and those which did not exhibit homogeneous variances. This homogeneity is supported by the significant p-value (<0.05) observed in the 'Based on Mean' section of the analysis.

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ISSN 2089-8703 (Print)
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Tabel 11. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Experiment - Control	4.13500	9.63826	1.82146	.39767	7.87233	2.270	27	.031

Table 11 demonstrates a statistically significant difference between the mean mathematical thinking test scores of students who received instruction incorporating educational games and those who did not. This significance is evident from the Sig. (2-tailed) value of <0.05. Furthermore, the mean score is notably higher in the class that benefited from educational games-based learning. Consequently, it can be inferred that students in classes employing educational games exhibit superior algebraic ability test scores compared to their peers who did not receive such instruction.

Upon examination of the diverse tests conducted, it is evident that educational games with contextual approaches constitute an effective pedagogical tool for enhancing students' algebraic thinking skills

Discussion

During the analytical phase, a performance and needs analysis was conducted. The performance analysis revealed that students required support in algebraic form and the instructional media employed by mathematics teachers. The findings indicated the media's alignment with student needs and its compatibility with the curriculum and learning materials. Moreover, an examination of student needs suggested a demand for engaging, practical, and innovative mathematics learning resources capable of stimulating student interest in the classroom. This aligns with the perspective of (Abdullah et al., 2018), who posit that educational games serve as effective learning tools for stimulating student engagement during the learning process. Based on these analyses, the researcher developed game-based media utilizing a contextual approach.

The Design phase involved the creation of learning objectives, media, media assessment tools, and learning technologies. The developed learning objectives were designed to measure the attainment of competencies related to algebraic concepts.

Subsequently, in the development phase, media products underwent validation by both media experts and content experts to assess their feasibility. The developed media were found to be both practical and of a high standard. In addition to the evaluation, experts provided feedback in the form of suggestions or minor

The media were then implemented in real-world classroom settings followed by an evaluation phase. The results indicated improved learning outcomes. This is attributed to the media's engaging design which incorporated visual elements such as colors, images, and animations, and its alignment with students' real-world experiences. These elements stimulated students' interest and curiosity, leading to more intensive use of the media and consequently, better learning achievements. This finding aligns with previous research on Game-Based Learning (Lagos et al., 2023)

ISSN 2089-8703 (Print)
ISSN 2442-5419 (Online)

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The results of the implemented learning media demonstrate that the average algebraic thinking ability of students who utilized this media is significantly higher than those who did not. This enhancement can be attributed to the rigorous development process, which involved multiple rounds of testing by material experts, media specialists, and educators to ensure practicality. These findings corroborate the research of (Bang et al., 2023) which concluded that game-based math learning is a valuable resource for enhancing student engagement, motivation, and confidence in mathematics. Moreover, (Yeh et al., 2019), observed a notable increase in students' mathematical achievement, particularly in calculation and word problem-solving, when using Game Math-Island. Additionally, (Kartika et al., 2019) found that integrating math adventure educational games into the teaching and learning process can effectively improve students' creative thinking abilities.

This customizable media can be adapted to various learning contexts, from elementary to tertiary levels, and incorporate diverse materials. The developed educational game is easily installed on Android OS-based smartphones with minimal storage requirements, facilitating the learning process in diverse environments and situations.

CONCLUSION AND SUGGESTION

The results of this study and subsequent discussion indicate that educational mathematics games utilising a contextual approach are not only practical but also of significant value in facilitating mathematics learning. Furthermore, the observed learning outcomes provide empirical evidence to support the claim that such games are effective pedagogical tools.

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