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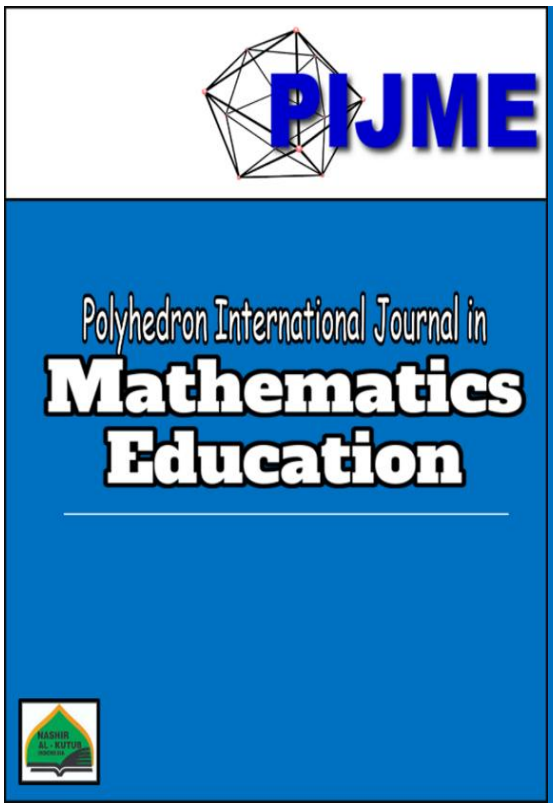

Effectiveness of digital-based mathematics learning media on sequence and series material

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Original Article

Effectiveness of digital-based mathematics learning media on sequence and series material

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Abstract
One of the mathematical topics closely related to real-life problems is sequences and series, which are used to model and predict various phenomena and patterns. This material helps enhance students' abilities in applying mathematical formulas accurately in everyday contexts. The aim of this study is to examine the effectiveness of digital-based learning media in supporting students' understanding of sequences and series. A simple descriptive quantitative method was employed, focusing on evaluating the media's effectiveness through basic statistical analysis. The results indicate that digital-based learning media are effective in facilitating students' comprehension of sequences and series material. These findings suggest that such media can be utilized in mathematics instruction to improve learning outcomes. However, further research is needed to evaluate the efficiency of this approach in broader learning contexts and to explore how it can be integrated with other instructional media to enhance students' overall academic performance. The implication of this research is that teachers should consider incorporating digital tools to complement traditional methods in teaching mathematical concepts. Additionally, curriculum developers are encouraged to design interactive and accessible digital content that aligns with students' learning needs and technological habits.

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1. Introduction

A country is said to be advanced or not can be seen from its education (Alfin, 2021). Education is a process of guidance, direction or leadership which contains elements such as educators, students, goals, and so on (Asyhari, 2016). The education of a nation is an indicator of the progress of human resources in it (Firmadani, 2020). This is a must for the state to continue to improve the quality of education so that it can gradually improve the quality of human resources in Indonesia, in accordance with the goals of national education summarized in Law of the Republic of Indonesia Number 20 of 2003 article 3 concerning the national education system (Yasin, 2023). Mathematics is an important and very useful science in everyday life (Yaumi, 2018). In addition, mathematics is included in the sciences that are the basis for the creation of modern technology so that mathematics becomes a mandatory learning at every level of education (Freiman, 2020; Semenov et al., 2023; Wahab, 2021). The objectives of learning mathematics contain formal and material mathematical values (Krutikhina et al., 2018), because if someone learns mathematics, then that person is able to do simple calculations that are practical and

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easy, so that it is expected to become a diligent, critical, thinking, logical, responsible person and able to solve problems (Dunne, 2015; Raharjo, 2021). However, in fact there are still many students who are less able to solve problems related to the application of mathematics (Habibie et al., 2023; Samudro, 2022). One of the mathematical materials related to everyday life problems is sequence and series material (Nasution, 2023). Sequence and series material is used to model and predict various phenomena and patterns. This material can hone students' abilities in operating mathematical formulas in everyday life properly and correctly (Wahab, 2021).

Various methods are used to encourage students to be able to operate mathematical formulas in everyday life. One of them is by using digital-based learning media that can be accessed anywhere and anytime by students (Harefa, 2024; Sudirman et al.,). The results of the researcher's observations, SMK Plus PGRI 01 Cibinong is a vocational school that requires grade XI students to do PKL so that many students are left behind in mathematics lessons. This is evidenced by the three classes from which data was taken totaling 113 students, there were 33% of students or around 37 students who took part in PKL. By providing appropriate digital learning media, it is hoped that students will easily access the material and be able to catch up on their shortcomings. In addition, the results of interviews with students that have been conducted show that students open their smartphones more often. One of the students also admitted that most students are lazy to read their textbooks. This shows that students are more comfortable using their smartphones for learning activities (Utari., 2022). Learning media that is often used in schools is math books. While in this digital era, there are many media that can support learning activities in the classroom, such as Quora, Quizizz, Canva, and iSpring Suite (Asmendri., 2022). Some of these media can make it easier for teachers to create digital-based learning media that can encourage students to want to learn mathematics and can improve student learning outcomes.

In several studies it has been proven that the use of digital-based learning media can improve student learning outcomes, (1) research conducted by Narestuti et al. (2021), entitled application of digital comic learning media to improve student learning outcomes proved that student learning outcomes increased from 54% to 93%; (2) research conducted by Wirawan et al. (2017) entitled development of digital archiving learning media to improve student learning outcomes at SMK Negeri 3 Surakarta proved that student learning outcomes increased from 69.26% to 80.59%, and (3) Research conducted by Novita and Sundari (2020) entitled improving student learning outcomes using digital snake and ladder game media proved that student learning outcomes increased from an average score of 74.42 to an average score of 84.02. iSpring Suite is a software that is directly connected to power point, the function of iSpring Suite itself is one of the media that helps someone to create interactive media that will later change into an android or laptop, so that the media that has been created using iSpring Suite will be easy to use or open anywhere. This makes many people interested in developing interesting learning media using iSpring Suite. Based on the background of the problem that has been explained above, the researcher sees the effectiveness of digital-based learning media on the Sequence and Series Material. Research Questions:

a) How effective is digital-based learning media developed using iSpring Suite in improving students' understanding of sequence and series material?
b) How do students perceive the use of digital-based learning media compared to traditional textbooks in learning mathematics, particularly in the topic of sequences and series?
c) To what extent can digital-based learning media help students who are left behind due to external activities such as internships to catch up on mathematics learning?

2. Method

2.1 Research Design

This study uses a quantitative descriptive research design, which is designed to analyze and describe the effectiveness of digital-based learning media on students' learning outcomes in the subject of sequences and series in mathematics. This research aims to assess whether the use of digital media can significantly improve students' understanding of this mathematical topic. The study involves a pretest-posttest design, where students' performances are compared before and after the intervention with digital-based learning media. This method allows for an assessment of learning improvements and the impact of digital media on students' comprehension of sequence and series concepts.

2.2 Research Participants

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The study was conducted in 2024 at a vocational high school (SMK) in Cibinong, specifically focusing on Grade XI students. A total of 15 participants were selected for this research. The participants were chosen based on their availability and willingness to engage with the digital-based learning media. This sample group was particularly relevant because many of these students had experienced interruptions in their mathematics learning due to participation in internships (PKL). These interruptions made them an ideal sample for evaluating how effective digital-based learning media can be in helping students who are behind in their mathematics education. The participants were selected using purposive sampling to ensure they met the necessary criteria for the research context.

2.3 Data Collection Techniques

To measure the impact of digital-based learning media, the study utilized pretest and posttest assessments. The following outlines the process of data collection:

(a) Pretest: A mathematics test was administered to the participants before they were introduced to the digital-based learning media. This pretest was designed to measure their initial understanding and competence in the sequence and series material. Digital-Based Learning Media Intervention: Following the pretest, the students were exposed to the learning content on sequences and series through digital-based learning media developed using iSpring Suite. The media included interactive elements, videos, and quizzes, designed to enhance students' understanding and engagement with the material. The learning media was accessible on both smartphones and laptops, catering to the preferences of the students.

(b) Posttest: After the students had completed the digital learning module, a posttest was administered. The posttest was identical in structure and content to the pretest, allowing for a direct comparison of students' performance before and after the intervention.

The pretest and posttest consisted of multiple-choice questions, short-answer questions, and problem-solving tasks specifically focused on sequences and series. These questions were designed to assess both conceptual understanding and problem-solving skills related to the material.

2.4 Data Analysis Techniques

The data collected from the pretest and posttest were analyzed using paired sample t-test (dependent t-test) to evaluate whether there was a statistically significant improvement in students' scores after the intervention with digital-based learning media. The paired t-test is appropriate for comparing the means of two related groups—in this case, the pretest and posttest scores of the same group of students.

The analysis was performed as follows:

Step 1: Calculate the mean and standard deviation of the pretest and posttest scores.

Step 2: Conduct the paired sample t-test to compare the pretest and posttest scores.

Step 3: Interpret the t-test results to determine if there was a significant difference between the pretest and posttest scores.

Hypothesis Testing

Null Hypothesis (H_0): There is no significant difference between the pretest and posttest scores after using digital-based learning media. Alternative Hypothesis (H_1): There is a significant difference between the pretest and posttest scores after using digital-based learning media. A significance level of $\alpha = 0.05$ was used for hypothesis testing. If the p-value from the t-test was less than 0.05, the null hypothesis would be rejected, indicating that the digital-based learning media had a significant impact on students' learning outcomes in sequence and series.

2.5 Ethical Considerations

Prior to conducting the study, informed consent was obtained from all participants, ensuring that they were fully aware of the research purpose and the procedures involved. Confidentiality was maintained throughout the study, with students' personal information anonymized in the data analysis.

Additionally, participation in the study was voluntary, and students had the right to withdraw at any point without consequence.

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3. Results and Discussion

3.1 Results

3.1.1 Descriptive Results of Classroom Implementation

The implementation of digital-based learning media for sequence and series material was carried out over a period of one week in the classroom. The 15 participants, all Grade XI students from a vocational high school in Cibinong, were introduced to the learning material through iSpring Suite digital media, which included interactive lessons, animated explanations, quizzes, and practice problems.

a) Introduction to the Digital Media: The students were first introduced to the digital-based learning media in a classroom setting, where the teacher explained the basic concepts of sequences and series. The students accessed the media via their smartphones and laptops, which allowed them to study at their own pace. The interactive nature of the content encouraged active participation and engagement, as students could immediately apply the concepts by solving practice problems directly within the media.
b) Learning Activities: Students worked individually on the provided digital materials, which included video tutorials on arithmetic sequences, geometric sequences, and series. They were then asked to solve related problems through embedded quizzes and instant feedback features within the media. The media also featured animated illustrations of sequences and series to help students visualize mathematical patterns and relationships.
c) Monitoring and Support: Throughout the learning process, the teacher provided real-time assistance by monitoring students' progress and addressing any difficulties they encountered. The teacher used the media's tracking features to assess which students were struggling with specific problems and offered additional explanations where necessary.
d) Post-Learning Reflection: After completing the digital lessons, students were asked to reflect on their learning experience through a brief survey. The feedback indicated that most students found the digital learning media engaging and easy to follow, with many reporting that they appreciated being able to learn at their own pace. Some students mentioned that the interactive quizzes helped reinforce their understanding, while others suggested improvements for future iterations of the media, such as including more real-life examples.
e) Posttest Implementation: The posttest was administered to all students after completing the digital-based learning session. The test consisted of questions similar to those found in the pretest, allowing for a direct comparison of students' performance before and after the intervention.

3.1.2 Hipotysis Results

To analyze the effectiveness of the development of the virtual classroom learning model is to process the data from the pretest and posttest results. To test the effectiveness of the national insight learning model that was developed, is to use the statistical test T-test for two groups of data from one sample group (paired) if the data analysis in the study is carried out by comparing the data before and after the treatment of one sample, then a comparative hypothesis is submitted with the t-test (Suharsimi Arikunto) as follows;

$$t = \frac{Md}{\sqrt{\frac{\sum xd2}{n(n-1)}}}$$

information:
di = the difference between the finished score and the previous score of each subject (i)
Md = Average of gain (d)
Xd = deviation of gain score from its mean (xd = di- Md)
X2d = square of deviation of gain score from its mean
N = number of samples (research subjects)
For hypothesis testing, the t value (tcount) above is then compared with the t value from the t distribution table (ttable). The method for determining the ttable value is based on a certain level of significance (eg $\alpha = 0.05$) and dk = n-1
Hypothesis testing criteria for one-sided right-sided tests, namely;
Reject H_0, if $t_{count} \geq t_{table}$ and

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Accept H_0, if $t_{count} \leq t_{table}$ and
T_{table} with dk-1 (α=0,05)= 1,761
Table 1
Digital-Based Learning Effectiveness Calculation

Subject	Pre-test	Post-test	Gain	Xd	Xd^2
	X	Y	(X-Y)		
1	53.3	80.0	26.7	6.0	35.6
2	50.0	83.3	33.3	12.6	159.6
3	63.3	86.7	23.3	2.6	6.9
4	66.7	90.0	23.3	2.6	6.9
5	76.7	93.3	16.7	-4.0	16.3
6	76.7	90.0	13.3	-7.4	54.3
7	73.3	80.0	6.7	-14.0	196.9
8	80.0	90.0	10.0	-10.7	114.5
9	63.3	80.0	16.7	-4.0	16.3
10	56.7	80.0	23.3	2.6	6.9
11	50.0	80.0	30.0	9.3	86.5
12	60.0	90.0	30.0	9.3	86.5
13	70.0	96.7	26.7	6.0	35.6
14	76.7	90.0	13.3	-7.4	54.3
15	73.3	90.0	16.7	-4.0	16.3
TOTAL					
Averege (Md)			20.7		
∑d			310.0		
$\sum Xd^2$					893.4
Akar (√)	2.062534271				
t_h	10.02003552				
T_{table} (n-1)	0.69				

The descriptive statistical analysis of students' pretest and posttest scores revealed a notable improvement in learning outcomes after the implementation of digital-based mathematics learning media on sequence and series material. The average gain score was 20.7, indicating that students' performance increased by this margin on average. The gain scores ranged from a minimum of 6.7 to a maximum of 33.3, showing that all students experienced improvement, albeit at varying levels. The total deviation from the mean (∑d) was 310.0, and the sum of squared deviations ($\sum Xd^2$) reached 893.4, reflecting moderate variability in individual learning gains. These descriptive statistics suggest that the intervention had a generally positive effect on student performance, as demonstrated by the consistent increase in posttest scores across all participants.

Calculation

$$t = \frac{Md}{\sqrt{\frac{\sum xd2}{n(n-1)}}}$$

$$md = \frac{\sum d}{n} = \frac{20,7}{15} = 310,0$$

$$t = \frac{310,0}{\sqrt{\frac{893.4}{15(15-1)}}} = 10.020$$

Based on the results of the t-test analysis, where tcount ≥ ttable (10.02 ≥ 0.69), it can be concluded that H_0 is rejected. This result shows that there is a statistically significant difference between students' pre-test and post-test scores in mathematics learning using digital-based media. At the 95% confidence level, the improvement in students' performance is not random but influenced by the treatment, namely the use of digital learning media. This indicates that

the media significantly contributed to students' better understanding of sequence and series material. The statistical evidence supports the effectiveness of the digital media in helping students absorb mathematical concepts more easily and actively engage with the learning process. Therefore, the use of such media can be considered a viable and impactful alternative to conventional learning methods, especially in supporting students with limited time and access, such as those who are involved in internships or vocational training activities.

3.2 Discussion

The selection of sequence and series material in this study is not arbitrary, but rather based on the real and recurring challenges faced by students in applying mathematical concepts to real-life problems. During preliminary observations and interviews, it was found that many students struggled when asked to connect abstract mathematical formulas to practical applications, such as predicting patterns, calculating financial installments, or solving growth-related problems. These difficulties demonstrate a significant gap between conceptual understanding and practical application, particularly in topics such as sequence and series that require both analytical thinking and contextual comprehension. Therefore, the researcher deliberately chose sequence and series material as the focus, with the aim of helping students bridge this gap by equipping them with tools and strategies to apply what they have learned in meaningful, real-world contexts.

To address these learning challenges, a combination learning model was implemented. This model integrates three instructional approaches: lectures, group discussions, and practice questions. Each method plays a critical role in supporting student learning. The lecture component provides the foundational knowledge, allowing the teacher to explain theoretical concepts such as arithmetic and geometric sequences and the related formulas. The discussion element, meanwhile, creates space for collaborative learning, where students can ask questions, clarify their understanding, and engage in peer explanation—an essential part of deeper learning. Finally, the practice component allows students to reinforce their understanding by applying what they've learned to both textbook and real-life problems. By blending these approaches, the model ensures that students are not passive recipients of information but active participants in constructing their own understanding.

This approach is grounded in Bloom's Taxonomy, which divides learning into three main domains: cognitive, affective, and psychomotor. The cognitive domain, which was the focus of this study, consists of six hierarchical levels: C1 (Remembering), C2 (Understanding), C3 (Applying), C4 (Analyzing), C5 (Evaluating), and C6 (Creating) (Ramdhani & Susanti, 2024). Each level represents a progressively deeper level of cognitive processing. In the context of this study, the emphasis was placed on C3 – Applying, which involves using learned material in new and concrete situations. At this level, students are expected not only to understand a concept but also to implement it in problem-solving scenarios. In mathematics education, applying refers to the ability to select and use appropriate formulas, methods, or principles to solve specific problems, particularly those that mirror real-life challenges.

To support students in achieving this level of cognitive competence, digital learning media was utilized—specifically, media developed using iSpring Suite, a tool that transforms PowerPoint slides into interactive, web-based learning objects. The choice of iSpring Suite was strategic. It allowed the researcher to create dynamic, visually engaging materials that could include not only text and images but also audio narration, quizzes, hyperlinks, and animations. The interactive nature of the media helped maintain student engagement while also allowing for self-paced learning. For example, a student struggling with the concept of a geometric sequence could replay the explanation, pause to take notes, or try a practice question embedded within the media before moving on.

The digital media was made accessible via Google Chrome (Gupta et al., 2023), which most students already use daily on their smartphones or school-provided computers (Murray et al., 2019). This ensured that students could access the material anytime and anywhere, particularly important for vocational students who often have to divide their time between school and internships (PKL). From observations and student feedback, it was evident that this accessibility made a significant difference. Many students reported that they revisited the material outside of class hours, especially before quizzes and exams. This flexibility not only empowered students to take control of their own learning but also helped those who were absent due to fieldwork to catch up on missed lessons.

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However, like any technology-based solution, the use of digital media was not without its limitations (Hallur et al., 2023). One of the most frequently mentioned challenges was the dependence on internet connectivity. While the media itself was well-designed and functioned smoothly under optimal conditions, some students experienced delays in loading or difficulty accessing certain features when the signal strength was weak. This was particularly problematic in areas where cellular reception is inconsistent or during school hours when many students are simultaneously accessing the network. In such cases, students needed to wait longer for the content to load or had to refresh the browser multiple times, which occasionally disrupted the learning flow.

Despite this minor drawback, the overall implementation of digital learning media proved to be highly effective, especially when paired with the structured learning model and a focus on the C3 level of Bloom's Taxonomy. Students were not only able to understand the theoretical concepts behind sequences and series, but also showed significant improvement in solving problems that required them to apply these concepts. For instance, many students demonstrated the ability to identify the type of sequence, select the appropriate formula, and compute the required values accurately. Moreover, through interactive quizzes and formative assessments embedded in the media, students received immediate feedback on their performance, helping them to correct misunderstandings in real time.

In terms of student engagement and motivation, the media also had a noticeable positive impact. The inclusion of visual aids, animations, and voiceovers catered to various learning styles, which helped maintain student interest throughout the learning process. Compared to traditional textbook-based instruction, the digital media provided a more immersive and enjoyable learning experience (Runisah et al., 2021). This is especially important for vocational school students who may not always be academically inclined but are responsive to hands-on and interactive learning formats (Shieh, 2012). Several students also noted that learning through digital media felt more relevant and aligned with the technology-driven environments they encounter during their internships.

The effectiveness of this intervention was also evident in the quantitative outcomes. Students' post-test scores showed a substantial increase when compared to their pre-test results. The average gain in scores indicated that students were not only learning but also retaining and applying the knowledge. Moreover, the t-test analysis showed a significant difference between the pre-test and post-test, confirming the success of the intervention statistically. These findings are in line with previous research that has highlighted the potential of digital media to enhance student learning outcomes across various subjects, including mathematics.

In conclusion, the use of digital-based learning media in the teaching of sequence and series material, supported by a blended instructional model and aligned with the cognitive domain of Bloom's Taxonomy, particularly C3 (Applying), proved to be a powerful approach in improving students' mathematical competence. While challenges related to internet connectivity must be addressed, the benefits far outweigh the drawbacks. The success of this approach suggests that schools, especially vocational institutions, should consider integrating similar digital learning tools into their curriculum to foster more effective, accessible, and engaging learning environments. Future studies could expand this model to other mathematical topics or explore hybrid solutions that also cater to offline use to overcome connectivity barriers.

4. Conclusions

The findings of this study suggest that the provision of appropriate digital learning media can significantly enhance students' access to learning materials and help them catch up on missed content or learning arrears. In today's educational context, especially in vocational and secondary schools, students face various challenges in managing their learning time effectively, particularly when they are involved in internship programs (PKL) or other extracurricular responsibilities. Digital learning media that are accessible through commonly used platforms, such as smartphones and browsers like Google Chrome, offer a flexible and convenient solution to these challenges. Students can revisit learning materials at any time, which supports independent and self-paced learning.

From the qualitative data gathered through interviews, it became apparent that students are highly engaged with their smartphones throughout the day. One recurring theme was that students tend to open their phones more often than they engage with their textbooks. One student even explicitly stated that

"most of us are lazy to read textbooks." This remark aligns with the broader trend in which printed learning resources are perceived as less attractive compared to digital formats. These observations reinforce the importance of designing learning experiences that align with students' current habits and preferences. Digital media, when well-designed and pedagogically grounded, serve as a bridge between students' learning needs and their technological engagement.

The implications of these findings are multifaceted. Firstly, teachers and instructional designers are encouraged to embrace digital tools not merely as supplementary resources but as integral components of instructional delivery. The development of digital modules or interactive learning content can help ensure that even students who are often absent or less motivated in conventional classroom settings can still participate in the learning process meaningfully. Secondly, educational institutions must consider supporting this transition by providing adequate infrastructure, such as reliable internet access and digital literacy training for both teachers and students. Additionally, curriculum developers should rethink how content is delivered to make it more compatible with digital platforms without compromising on academic rigor. In conclusion, integrating digital learning media not only meets students where they are but also promotes greater accessibility, flexibility, and engagement. The shift toward digital formats must be accompanied by thoughtful instructional strategies and institutional support to truly maximize its potential in enhancing mathematics learning outcomes.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this article.

Declarations

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments. Informed consent was obtained from all individual participants included in the study.

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