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Effectiveness of Digital Learning Media on Students' Achievement in Science Education: A Quasi-Experimental Study in Islamic Junior Secondary School

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Abstract – *The rapid expansion of digital technology compels schools to adopt learning media that elevate achievement and cultivate twenty-first-century competencies. In science education, conventional teacher-centered instruction often fails to sustain engagement or deepen conceptual understanding, creating an urgent need for evidence-based innovations. This study examined the effectiveness of digital learning media in improving science achievement at MTs Muhammadiyah Datarang, an Islamic junior secondary school. A quantitative quasi-experimental design was implemented with two intact classes: an experimental group (n = 27) taught using digital media and a control group (n = 26) taught conventionally. Data were collected via pretest–posttest instruments and analyzed using descriptive statistics, normalized gain (N-Gain), and independent-samples t tests. Results showed that the experimental group attained a mean posttest score of 91.41 and an average N-Gain of 0.70 (high), whereas the control group achieved a score of 80.42 and a N-Gain of 0.27 (low); the difference was statistically significant ($p < 0.05$). These findings indicate that digital media enhance conceptual understanding, engagement, and motivation compared with traditional instruction. The study's novelty lies in providing rigorous quantitative evidence from a madrasah context that is underrepresented in the technology-enhanced science learning literature. Integrating interactive, visual, feedback-oriented tools can transform science learning in Islamic schools by enabling deeper processing and more equitable progress. This research contributes to physics education by presenting a practical model aligned with multimedia learning theory, providing classroom benchmark values, and informing teacher development and school-level policy. Future studies should extend the intervention longitudinally, involve larger and more diverse samples, and examine affective and social outcomes to evaluate the sustainability and generalizability of the gains.*

Keywords: *digital learning media; student achievement; science education; quasi-experimental; Islamic school*

I. INTRODUCTION

The integration of digital technology into education has become a cornerstone in the pursuit of quality, equity, and competitiveness in human resource development. In the era of globalization and rapid technological change, education faces increasingly complex challenges, particularly in

improving the quality and relevance of learning processes. Conventional teacher-centered instruction, although still widely practiced, is often criticized for being insufficiently engaging and less capable of cultivating deep conceptual understanding, particularly in science education. To address these shortcomings, innovation in both learning methods and media is essential. Innovation in education refers to the introduction of new strategies, approaches, or tools within the learning system that can effectively resolve pedagogical problems and enhance outcomes (Andriani et al., 2021; Yunika, 2023). One such innovation is the implementation of digital learning media, which has become an increasingly prevalent pedagogical response to the demands of the digital age.

Digital learning media encompasses a diverse range of technological tools, including educational videos, interactive applications, simulations, and online platforms designed to support the delivery of instructional content and foster student engagement (Setiyawan, 2021). These media formats allow teachers to present abstract concepts visually and contextually, thus helping learners to better understand complex materials in science subjects. The effectiveness of digital media can be evaluated through quantitative measures that compare learning outcomes before and after its application, thereby providing empirical evidence of its pedagogical value (Sri et al., 2025). Moreover, digital learning is aligned with the competencies required in the twenty-first century, such as technological literacy, critical thinking, creativity, and problem-solving. When appropriately implemented, digital learning media can serve as a vehicle for cultivating these competencies and preparing students for the challenges of modern society (Maruf et al., 2024; Mubarrok et al., 2025).

Despite these advantages, the transition from traditional classroom teaching to digitalized learning requires careful consideration of pedagogical design and contextual suitability. Previous research has highlighted the transformative potential of technology integration in teaching and learning processes. For instance, gadget-based learning through mobile devices, once considered unconventional in schools, has now become an accepted practice in various educational settings (Akuarta et al., 2025). The digitalization of education has thus shifted learning patterns toward more interactive and learner-centered models, enabling students to construct knowledge and collaborate in meaningful ways actively. Furthermore, e-learning, as a broader framework encompassing online, blended, and hybrid models, has significantly altered the way educational institutions deliver and manage learning activities. These innovations are not merely technological upgrades but represent systemic changes in pedagogy, assessment, and learner engagement.

The core problem addressed in the current study is the limited effectiveness of conventional, teacher-centered methods in enhancing student achievement in science subjects. Science learning,

particularly at the junior secondary level, demands instructional approaches that go beyond rote memorization and instead foster conceptual understanding, inquiry, and application. However, many classrooms continue to rely on traditional methods, resulting in limited student engagement and suboptimal learning outcomes. To address this issue, digital media presents a promising solution by offering interactive, visual, and contextual representations of science concepts, thereby making abstract ideas more accessible. Such solutions are particularly relevant in light of global educational trends that emphasize student-centered learning and the integration of technology to promote deeper cognitive engagement (Maruf et al., 2024; Mubarrok et al., 2025).

Previous empirical evidence has demonstrated the effectiveness of technology-based media in improving student outcomes across various educational contexts. For example, Nasar et al. (2025) developed a PhET-based instructional approach that successfully enhanced higher-order thinking skills in physics, while Irawan et al. (2025) reported that computer-based interactive videos significantly improved students' understanding of static fluid concepts. Similarly, integrated Quizizz into contextual teaching and learning, resulting in notable gains in student performance. These findings align with the broader theoretical framework of multimedia learning, which posits that learning is more effective when information is presented through multiple modalities such as text, visuals, and audio (Mayer, 2017). Collectively, these studies indicate that digital media provides a robust pedagogical solution to the shortcomings of traditional methods in science education.

In the broader landscape of digital learning research, studies have consistently shown that digital-based media contribute positively to academic achievement. For instance, Puspitasari et al. (2023) demonstrated significant improvement in students' science achievement through the application of digital learning tools at SD Muhammadiyah Condongcatur. Similarly, Ayuwandira and Chotimah (2023) found that e-learning-based instruction at MTs Muhammadiyah Wuring enhanced performance in social science subjects. Other studies, such as those by Fatma and Ichsan (2022) and Nasution (2023), highlighted the role of digital learning media, including Genially, PowerPoint, and interactive physics applications in increasing motivation, engagement, and achievement. However, the majority of these studies were conducted in general school settings, and only limited research has focused on madrasah (Islamic school) contexts. This represents a crucial gap, as Islamic educational institutions often face unique challenges in adopting digital technologies due to differences in curriculum design, resource allocation, and pedagogical orientation.

A closer examination of the existing literature reveals that while the benefits of digital learning media are widely acknowledged, their application in science education within madrasah remains underexplored. Studies that specifically evaluate the effectiveness of digital media in

madrasah contexts using rigorous quantitative methods are scarce. This gap is significant because madrasahs, as institutions that combine religious and general education, play a critical role in shaping student competencies and character. Integrating digital media into science education within madrasahs could bridge the divide between traditional religious values and modern educational demands. Furthermore, empirical evidence from such contexts is vital to inform policy-making and guide teachers in designing effective and culturally responsive instructional strategies.

Therefore, this study aims to analyze the effectiveness of digital learning media in improving student achievement in science at MTs Muhammadiyah Datarang (an Islamic junior secondary school). By employing a quasi-experimental design involving both experimental and control groups, the study provides measurable evidence of the impact of digital media on student performance. The novelty of this research lies in its specific focus on the madrasah context, where systematic investigations of digital media effectiveness in science learning are still limited. This study not only seeks to verify the positive contributions of digital media to student learning outcomes but also to provide empirical evidence that can serve as a foundation for teachers and educational institutions in adopting technology-integrated strategies.

II. METHODS

This study employed a quantitative approach with a quasi-experimental design to examine the effectiveness of digital learning media in improving students' achievement in science subjects at MTs Muhammadiyah Datarang. The quasi-experimental design was chosen because it allows researchers to investigate causal relationships under classroom conditions where random assignment of participants is not feasible, thereby maintaining ecological validity in real educational contexts (Setyosari, 2020). The study adopted a pretest–posttest control group design, involving one experimental group exposed to digital learning media and one control group taught using conventional instructional methods. This design enabled a systematic comparison of learning outcomes across groups while controlling for initial differences in prior knowledge.

The research procedure was carefully structured to ensure both validity and reliability of the findings. At the outset, both groups of students were administered a pretest to establish a baseline understanding of the targeted science concepts. The experimental group then received instruction using digital media, including interactive videos and app-based simulations, while the control group was taught using traditional teacher-centered strategies without technological integration. Following the instructional sessions, both groups were administered a posttest that paralleled the pretest in terms of content and difficulty, thereby enabling direct measurement of learning gains.

The overall flow of the research design is illustrated in Figure 1, which depicts the sequence of pretest administration, treatment differentiation, posttest assessment, and subsequent data analysis. This design is widely recognized in educational research as effective for evaluating the impact of instructional innovations (Ebenezer & Lion, 2023).

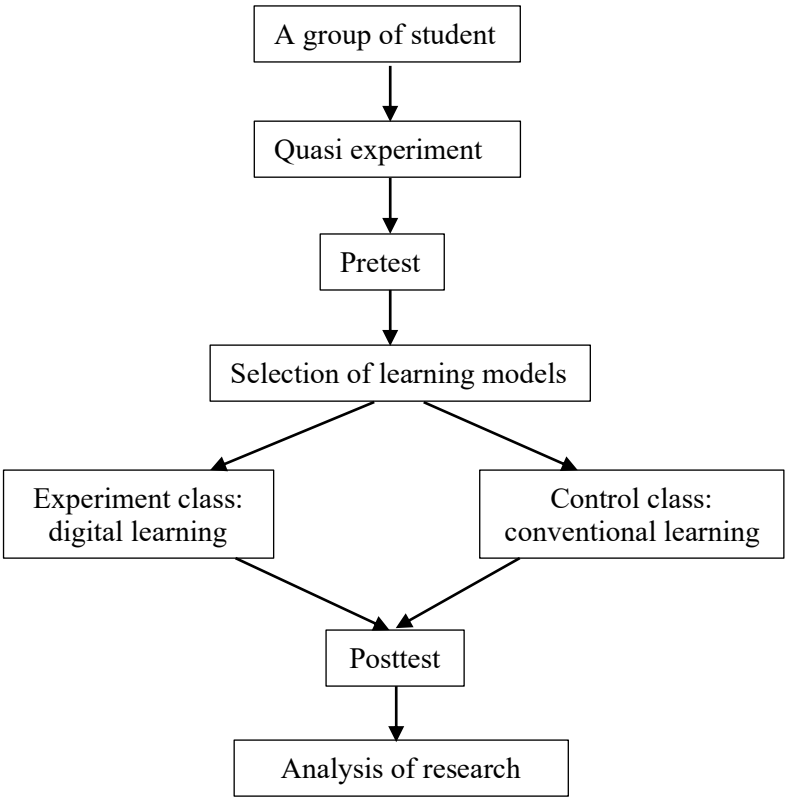

Figure 1. Flowchart of the research procedure using a pretest-posttest control group design

The specific structure of the research design is presented in Table 1. Here, the experimental class (VIII B) was exposed to treatment with digital learning media (X), while the control class (VIII A) received instruction using conventional methods (Y). Both groups completed a pretest (O1 and O3, respectively) and a posttest (O2 and O4), allowing for direct comparisons of achievement gains. The inclusion of parallel assessments before and after treatment facilitated the calculation of mean differences and normalized gain (N-Gain), which serve as indicators of instructional effectiveness. This structure reflects best practices in quasi-experimental educational research, where systematic controls help isolate the impact of the instructional variable under investigation (Dolch et al., 2021).

Table 1. Research design

Class	Pretest	Treatment	Post test
Experiment	O_1	X	O_2
Control	O_3	Y	O_4

Where X: Learning using digital media; Y: Conventional learning method; O1: Pretest experimental group; O2: Posttest experimental group; O3: Pretest control group; O4: Posttest control group.

The population of the study consisted of 53 eighth-grade students enrolled at MTs Muhammadiyah Datarang in the academic year 2024/2025. From this population, two intact classes were designated as research samples. Class VIII A, comprising 26 students, was assigned as the control group, while Class VIII B, with 27 students, served as the experimental group. This sampling procedure was purposive, based on recommendations from subject teachers who confirmed that students across classes had comparable academic abilities, as the school does not categorize students as superior or regular (Asari et al., 2023). The absence of significant ability differences across classes ensured that the assignment of experimental and control conditions was appropriate.

The research was conducted at MTs Muhammadiyah Datarang, located in Gowa Regency, South Sulawesi Province, Indonesia. This setting was chosen because the school is actively engaged in integrating technology into its teaching practices, yet faces challenges in optimizing student achievement in science subjects. Conducting the study in this context thus provided an opportunity to investigate the practical utility of digital media in a real madrasah environment, offering both theoretical and practical contributions to the field.

Instruments used for data collection included learning achievement tests, student engagement questionnaires, and interview protocols. The achievement tests, consisting of multiple-choice and essay questions, were aligned with the science curriculum and competency indicators, ensuring both relevance and construct validity (Marthiani, 2024). The student engagement questionnaire employed a Likert scale format to capture levels of participation and interest, particularly in the experimental group using digital media. Meanwhile, interviews with teachers and selected students provided complementary qualitative insights into experiences, perceptions, and challenges encountered during the intervention. To guarantee accuracy and consistency, all instruments underwent expert validation, including content validity testing using Aiken's V and reliability testing via Cronbach's Alpha, with a minimum acceptable threshold of $\alpha \geq 0.70$ (Bala & Thakur, 2023; Mejía-Clavo et al., 2024; Zayrin et al., 2025; Amalia et al., 2022). Instruments meeting these criteria were deemed appropriate for deployment in the study.

Data analysis followed a systematic sequence, beginning with descriptive statistics to provide an overview of student performance before and after treatment. These included measures of central tendency (mean, median, and mode) as well as variability (standard deviation and range), thereby capturing both general trends and distributional characteristics of scores (Dolch et al., 2021; Wang, 2024). To examine the effectiveness of digital learning media, inferential statistics were applied. An independent samples t-test was conducted to compare the posttest means of the experimental and control groups, thereby assessing the statistical significance of observed differences (Ebenezer & Lion, 2023). In addition, normalized gain (N-Gain) analysis was performed to quantify the degree of improvement achieved by students relative to their maximum potential gain. The N-Gain metric is widely used in science education research because it accounts for differences in baseline scores, providing a fairer evaluation of instructional impact. The categorization of N-Gain values into high (≥ 0.7), moderate (0.3–0.7), and low (< 0.3) further allowed for a nuanced interpretation of instructional effectiveness.

To enhance reliability, the instructional sessions for both groups were conducted simultaneously under comparable classroom conditions, thereby minimizing external influences (Sugiyono, 2019). Observational notes were also taken to document behavioral patterns, student responses, and contextual factors that could inform the interpretation of quantitative results. Combining these methods provided a more comprehensive understanding of the instructional dynamics and outcomes, consistent with recommendations for methodological rigor in educational research (Litina & Rubene, 2024; Fajri et al., 2024).

III. RESULTS AND DISCUSSION

The analysis of pretest and posttest scores in the experimental group revealed a consistent and substantial improvement in students' achievement following the integration of digital-based learning media. As illustrated in Figure 2, all 27 students in the experimental class demonstrated progress from their initial performance. Pretest scores ranged between 66 and 83, indicating moderate variability in baseline understanding of science concepts. After the intervention, posttest results showed marked improvement, with scores spanning from 83 to 100.

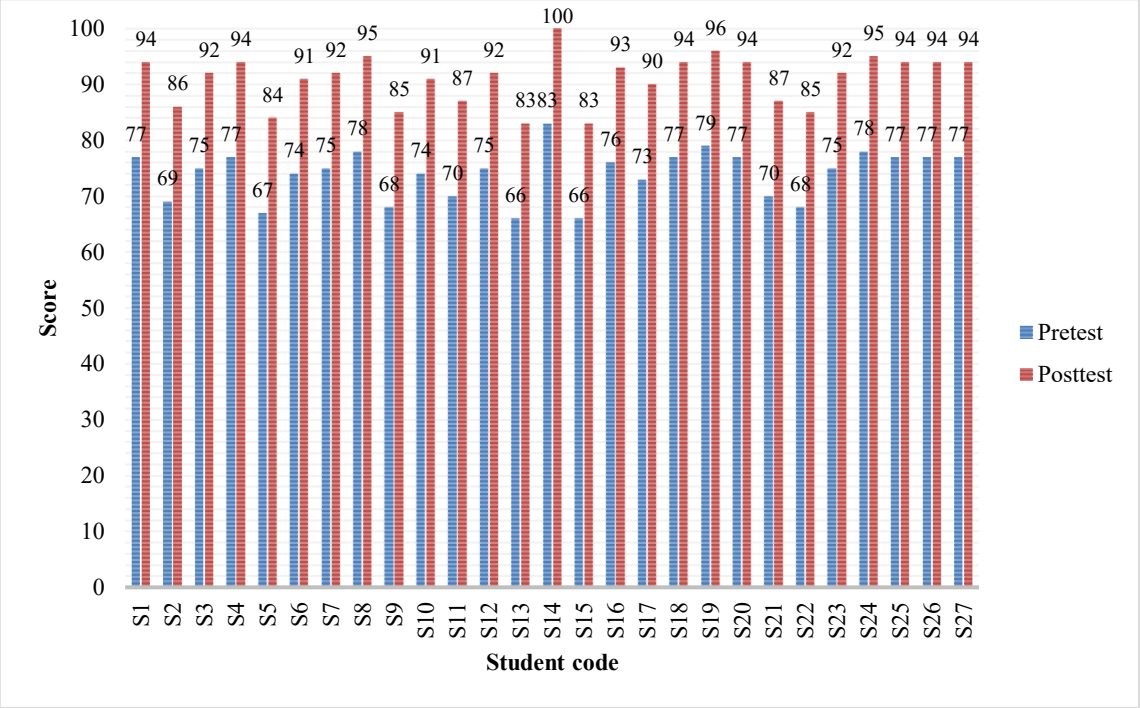

Figure 2. Pretest and posttest results of experimental group students

The highest individual achievement was recorded by student S14, who advanced from a pretest score of 83 to a perfect posttest score of 100. The lowest posttest scores, obtained by students S13 and S15, were 83, still representing notable gains from their pretest results. On average, students' scores increased by approximately 15 to 17 points across the class. This consistent upward trend highlights the effectiveness of digital media in promoting conceptual understanding, as evidenced by the benefits gained by every student.

The class mean rose from 73.74 in the pretest to 91.41 in the posttest, categorizing the experimental group as high performing following the treatment. These findings suggest that digital-based media not only enhanced comprehension of abstract science concepts but also promoted active engagement and motivation among learners. The uniformity of improvement across students highlights the inclusivity of this approach, demonstrating that interactive and contextualized digital strategies can support both higher-and lower-achieving students within the same learning environment.

The performance of students in the control group, who received instruction through conventional methods, also showed improvement, although the gains were relatively modest compared to the experimental group. As depicted in Figure 3, all 26 students demonstrated some degree of progress from pretest to posttest.

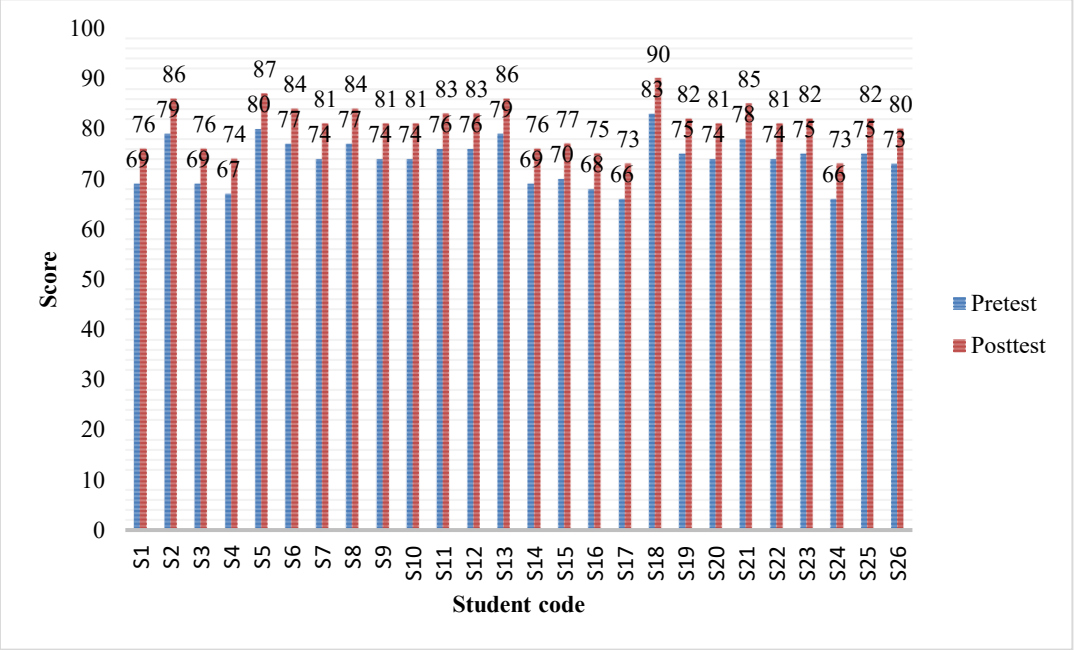

Figure 3. Pretest and posttest results of the control group students

Pretest scores in this group ranged from 66 to 83, suggesting comparable baseline abilities to those of the experimental group. After instruction, posttest scores rose to a range of 73 to 90. Student S18 achieved the highest posttest performance with a score of 90, while the lowest outcomes, recorded by students S17 and S24, were 73. These results indicate a consistent, albeit limited, increase across the class. The mean score improved from 73.35 in the pretest to 80.42 in the posttest, reflecting an average gain of approximately 7 points. While this demonstrates that conventional instruction facilitated incremental progress, the magnitude of improvement was noticeably lower than that observed in the experimental group. The relatively narrow increase suggests that traditional approaches may be effective for reinforcing foundational understanding but less impactful in fostering deeper conceptual mastery and engagement.

The summary of descriptive statistics is presented in Table 2, which compares mean pretest and posttest scores for both groups. The pretest averages were nearly identical—73.35 for the control group (n = 26) and 73.74 for the experimental group (n = 27)—with only a 0.39-point difference. This parity indicates that both groups began with comparable baseline abilities, thereby supporting the internal validity of the quasi-experimental design and ensuring that subsequent differences in outcomes can be attributed to the instructional treatments rather than to initial disparities in ability.

Table 2. Descriptive statistics of control and experimental groups

Group	N	Mean pretest	Mean post-test	Mean difference
Control	26	73.35	80.42	7.07
Experimental	27	73.74	91.41	17.67

The descriptive statistical analysis revealed that both groups started from nearly identical baselines, with mean pretest scores of 73.35 for the control group and 73.74 for the experimental group, a negligible difference of only 0.39 points. After the intervention, the control class improved modestly, gaining 7.07 points to reach a posttest mean of 80.42, indicating that conventional instruction produced stable but limited progress. In contrast, the experimental group showed a substantial gain of 17.67 points, increasing its average score to 91.41, which clearly demonstrates the effectiveness of digital-based instruction. The 10.6-point difference in gains between the two groups highlights the superior capacity of digital media to accelerate learning and foster deeper conceptual understanding compared to traditional approaches. These findings suggest that while both methods support learning improvement, the digital intervention provided a more transformative impact by enhancing interactivity, visualization, and motivation among students. Overall, the descriptive evidence strongly supports the conclusion that digital learning media are significantly more effective than conventional instruction in promoting academic achievement in science subjects.

To provide a more equitable assessment of learning improvement, this study employed the normalized gain (N-Gain) index, which measures student progress relative to the maximum possible gain. The N-Gain is calculated using the formula

$$N\text{-}Gain = \frac{posttest\ value - pretest\ value}{ideal\ value - pretest\ value} \quad (1)$$

The results are categorized into three levels: high (≥ 0.7), moderate ($0.3 \leq g < 0.7$), and low (< 0.3). This approach offers a more accurate measure of instructional effectiveness, as it accounts for differences in baseline performance and evaluates student progress proportionally rather than absolutely.

As illustrated in Figure 4, the comparison between the control and experimental groups shows a marked difference in outcomes. The control group recorded an average pretest score of 73.35, which increased modestly to 80.42 in the posttest, producing an average N-Gain of only 0.27. This low value places the control class in the “less effective” category, suggesting that conventional instruction produced only incremental learning gains. By contrast, the experimental

group began with a comparable pretest average of 73.74 but achieved a much higher posttest mean of 91.41, resulting in an average N-Gain of 0.70. This value reaches the threshold of the "high" category, confirming that digital-based learning media were highly effective in improving students' conceptual understanding of science.

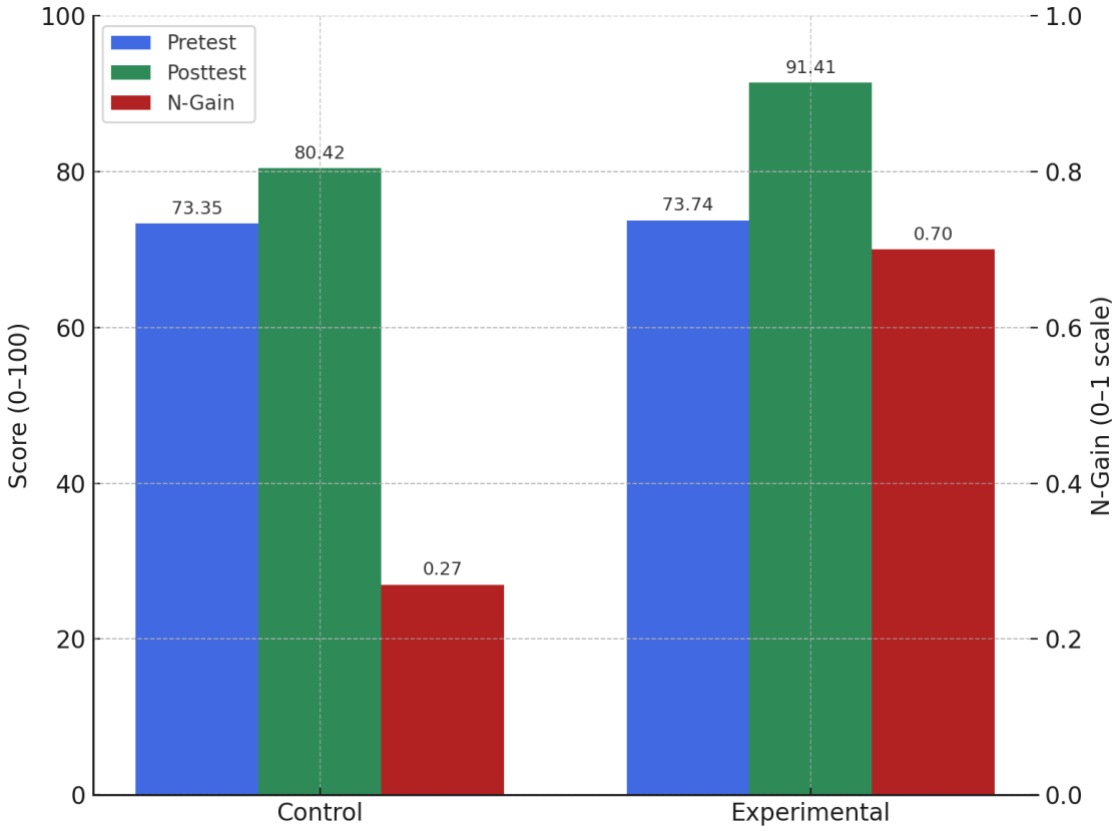

Figure 4. Comparison of average pretest, posttest, and N-Gain scores between control and experimental groups

The difference between the two groups is striking: while both started from nearly identical baselines, the experimental group achieved more than double the learning gain of the control group. This finding reinforces the conclusion that digital media provided not only higher raw achievement but also deeper and more equitable progress relative to students' initial knowledge levels. The proportional improvement captured by the N-Gain metric thus strengthens the argument that technology-enhanced learning strategies are more transformative than conventional methods in fostering science learning outcomes.

The results of this study provide compelling evidence that digital-based learning media are significantly more effective than conventional approaches in improving student achievement in science subjects at the junior secondary level. The experimental group's substantial gains in both posttest scores and normalized gain (N-Gain) values demonstrate that digital media can facilitate deeper conceptual understanding and enhance learner engagement. These findings are consistent

with Mayer's (2017) multimedia learning theory, which posits that students learn more effectively when instructional materials combine verbal explanations with visual representations, thereby engaging dual channels of information processing and reducing cognitive overload. The consistent improvements observed in the experimental group confirm that digital resources, such as interactive simulations and video-based applications, foster environments conducive to active and meaningful learning.

The improvement in student outcomes through digital media is further supported by earlier empirical studies. Nasar et al. (2025) demonstrated that the integration of PhET-based simulations in physics instruction strengthened higher-order thinking skills, while Irawan et al. (2025) showed that computer-based interactive videos enhanced understanding of static fluid concepts. Similarly, reported significant learning gains when contextual teaching and learning strategies were combined with Quizizz. The present findings align with this body of evidence, highlighting the transformative effect of interactive technology on student learning, especially in science education, where abstract concepts often pose challenges to comprehension.

A notable aspect of the findings is that all students in the experimental group experienced improvement, regardless of their initial performance levels. This inclusivity reflects the capacity of digital learning media to address diverse learning needs by providing visualizations, interactivity, and immediate feedback that support both high- and low-achieving students. Pokhrel (2024) has argued that digital technologies enable differentiated instruction by allowing learners to engage with content at their own pace, thereby reducing achievement disparities. In the current study, this was evident in the narrowing of performance gaps within the experimental class, suggesting that digital media may contribute to more equitable learning outcomes compared to conventional methods.

The comparative analysis between the experimental and control groups also reinforces the pedagogical superiority of digital instruction. The control group, which relied on conventional teacher-centered methods, achieved only incremental improvements, with an average N-Gain value of 0.27, categorized as low. In contrast, the experimental group achieved an average N-Gain of 0.70, falling within the high category and indicating a more significant conceptual transformation. This sharp difference illustrates that while traditional methods may sustain basic comprehension, they lack the capacity to produce the deeper learning gains associated with interactive and student-centered digital environments. These results are in line with findings from Fatma and Ichsan (2022), who observed that the integration of digital platforms such as Genially improved student outcomes in elementary science classes, and with Nasution's (2023) meta-analysis, which concluded that interactive physics media consistently produced positive learning effects.

The findings also have particular significance for the context of Islamic junior secondary schools, or madrasahs, where empirical evidence on the effectiveness of digital media remains limited. While prior research has focused largely on public schools (Puspitasari et al., 2023; Ayuwandira & Chotimah, 2023), the present study demonstrates that technology integration can be successfully implemented in religious-based educational institutions. Haddade et al. (2023) emphasized that technology-based learning strategies in madrasahs enhance student engagement and achievement when appropriately aligned with curricular and cultural values. Restalia and Khasanah (2025) further highlighted that digital transformation in Islamic education opens opportunities for innovation while maintaining the integrity of religious traditions. The current findings contribute to this discourse by providing quantitative evidence that digital learning media substantially improve science learning outcomes in a madrasah setting.

From a broader theoretical perspective, the findings underscore the relevance of twenty-first-century learning frameworks, which emphasize technological literacy, critical thinking, and problem-solving skills as essential competencies (Maruf et al., 2024; Mubarrok et al., 2025). By engaging students in interactive digital environments, this study demonstrates that science education can move beyond rote memorization to cultivate higher-order cognitive processes. This is especially significant in light of research by Fajri et al. (2024), who found that digital competence and access to quality media were strongly correlated with academic achievement, and by Litina and Rubene (2024), who argued that digital school cultures enhance scientific literacy and critical thinking. In this regard, the current study not only affirms the potential of digital media for improving academic performance but also highlights its role in preparing learners for the demands of the modern knowledge economy.

IV. CONCLUSION AND SUGGESTION

The findings of this study demonstrate that the use of digital-based learning media significantly enhances students' academic achievement in science at the junior secondary level. Quantitative results revealed that the experimental group, which received instruction through digital media, achieved a mean posttest score of 91.41 with an average N-Gain of 0.70, categorized as high. In contrast, the control group, taught using conventional methods, achieved a mean posttest score of 80.42 and an average N-Gain of 0.27, which is categorized as low. The 10.6-point difference in achievement gains between the two groups confirms the superior effectiveness of digital learning media in fostering conceptual understanding, student engagement, and motivation. These findings provide robust empirical evidence that digital

instructional strategies are more transformative than traditional approaches in supporting science learning.

Despite these promising results, the study has several limitations. The research was limited to a single institution with a relatively small sample of 53 students, which restricts the generalizability of the findings. The intervention was also conducted over a short period, leaving the long-term effects of digital media on knowledge retention unexamined. Future research should therefore consider longitudinal designs, larger and more diverse samples, and an exploration of affective and social learning dimensions such as motivation and collaboration. Nevertheless, this study makes a meaningful contribution to the field of physics education by providing empirical evidence from a madrasah context, which remains underexplored in the literature. It underscores the potential of digital media not only to improve learning outcomes but also to align science education with the competencies required in the twenty-first century.

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