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THE TRANSFORMATION OF LEARNING IN THE DIGITAL ERA: TEACHERS' PERSPECTIVES ON DIGITAL MEDIA USE AND ITS IMPLICATIONS FOR SCIENCE EDUCATION

Nurdini Nurdini[1)*], Solehkun Kodir[2)], Nuzulira Janeusse Fratiwi [3)], Hera Novia [4)], Nur Habib Muhammad Iqbal[5)]
[1,3,4,5)] Physics Education Program, Universitas Pendidikan Indonesia, Indonesia
[2)] Branch VII of the Regional Education Office, West Java Province, Indonesia
*Corresponding author: nurdini@upi.edu

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Abstract:
This study aims to explore junior secondary school teachers' perspectives on the use of digital media and its implications for the transformation of science education in the digital era. This study employed a survey research design. Data were collected from 1,622 teachers across 38 provinces in Indonesia using a structured questionnaire encompassing five key domains: the intensity and types of digital media use, challenges in implementation, expected forms of support, and the impact on the learning process. The instrument underwent expert validation by three specialists in educational technology and science education. The content validity results indicated an S-CVI score of 0.95 for content relevance, 0.93 for clarity of wording, and 0.93 for alignment with the research objectives. Data were analyzed using descriptive statistics to summarize the trends in teacher responses. The results show that 87.8% of teachers were accustomed to using digital technology in learning, with the highest frequency of use falling under several times per week (64.8%). The main barriers identified were limited device access (67.7%), unstable internet connectivity (60.7%), and insufficient training (56.6%). Most teachers emphasized the need for sustainable and subject-relevant digital competency training. The findings highlight that the transformation of science education in the digital era depends not only on infrastructure availability but also on the pedagogical capacity of teachers to utilize digital media in contextual, exploratory, and, scientific ways.

Keywords: digital transformation, learning media, science education, teachers' perspectives

Abstrak:
Penelitian ini bertujuan untuk mengeksplorasi perspektif guru sekolah menengah pertama terhadap penggunaan media digital serta implikasinya terhadap transformasi pembelajaran sains di era digital. Jenis penelitian yang digunakan yaitu survey. Data diperoleh dari 1.622 guru di 38 provinsi di Indonesia melalui kuesioner terstruktur yang mencakup lima domain utama: intensitas dan jenis penggunaan media digital, kendala implementasi, dukungan yang diharapkan, dan dampak terhadap proses pembelajaran. Instrumen telah divalidasi ahli oleh tiga pakar dalam bidang teknologi pendidikan dan pendidikan sains. Hasil validitas isi menunjukkan nilai S-CVI sebesar 0,95 untuk kesesuaian isi, 0,93 untuk kejelasan redaksi, dan 0,93 untuk kesesuaian dengan tujuan penelitian. Data dianalisis secara deskriptif untuk mengidentifikasi pola tanggapan guru. Hasil menunjukkan bahwa 87,8% guru telah terbiasa menggunakan teknologi digital dalam kegiatan pembelajaran, dengan frekuensi penggunaan tertinggi berada pada kategori beberapa kali dalam seminggu (64,8%). Kendala utama dalam integrasi media digital adalah keterbatasan perangkat (67,7%), koneksi internet yang tidak stabil (60,7%), dan kurangnya pelatihan (56,6%). Mayoritas guru menyatakan bahwa pelatihan kompetensi digital yang relevan dan berkelanjutan merupakan solusi utama yang dibutuhkan. Temuan ini menunjukkan bahwa transformasi pembelajaran sains di era digital tidak hanya bergantung pada ketersediaan infrastruktur, tetapi juga pada kapasitas pedagogis guru dalam memanfaatkan media digital secara kontekstual, eksploratif, dan ilmiah.

Kata kunci: transformasi digital, media pembelajaran, pembelajaran sains, perspektif guru

INTRODUCTION

Digital transformation in education is a response to global changes in the era of the Industrial Revolution 4.0, which demands a more adaptive, flexible, and technology-based learning system (Dina Destari, 2023; Siswanto, 2022; Yuangga, 2023). In the context of primary and secondary education, digitalization goes beyond the provision of devices and internet access; it also involves a paradigm shift that positions technology as an integral component of the teaching and learning process (Chowdhary, 2019; Khan & Alamri, 2017; Patil, 2022). Several empirical studies have revealed a digital adoption gap among teachers, particularly science teachers in non-urban areas. (Rusydiyah et al., 2024) reported that the level of digital transformation readiness among rural science teachers is significantly lower than that of their urban counterparts. This lack of integration has implications for the quality of science education, as abstract scientific concepts often require visualization, simulation, and exploration through digital means (El Kharki et al., 2021; So et al., 2019). Consequently, digital transformation requires not only access to technological infrastructure but also the pedagogical competence of teachers—particularly science teachers—to effectively integrate digital media into classroom instruction in ways that support contextual, exploratory, and scientific learning.

Digital learning media encompass a wide range of formats, including instructional videos, electronic modules, interactive animations, infographics, and learning management system platforms. The use of digital media is believed to enhance student engagement, clarify abstract concepts, and provide more meaningful and contextual learning experiences (Greve et al., 2022; Lee & Roger, 2023; Yates et al., 2021). On the other hand, the effectiveness of these media depends greatly on teachers' pedagogical ability to select, adapt, and implement them within appropriate instructional scenarios (Artini & Sujana, 2022; Fajar et al., 2022). Therefore, understanding teachers' perspectives on the use of digital media is crucial for designing targeted policies and professional development strategies (Wang, 2023).

Previous studies have shown that the main challenges in implementing digital learning include limited access to devices, uneven internet availability, and the varying levels of digital competence among teachers (Chan & Zary, 2019; Sikora et al., 2023; Szyszka et al., 2022). Nevertheless, many teachers have expressed enthusiasm for using technology in instruction, especially during periods of remote learning. However, there remains a lack of research that specifically explores teachers' perceptions on a broader scale in the context of digital learning transformation, particularly in relation to science education. Understanding teachers' perspectives is essential, as their beliefs, confidence, and classroom practices directly influence how digital tools are selected and applied. Without such exploration, the integration of digital technology in science education may lack depth and alignment with instructional needs, potentially reducing its effectiveness in supporting the visualization of abstract scientific concepts.

Science education has unique characteristics that require visual, experimental, and inquiry-based approaches. Challenges in explaining abstract concepts such as atomic structure, forces and motion, or thermal phenomena can be minimized through the appropriate use of digital media. Previous studies have demonstrated that the use of simulations and virtual laboratories can significantly improve students' understanding of scientific concepts (El Kharki et al., 2021; Mashami et al., 2023; Yap et al., 2021). Therefore, teachers' perspectives on digital media can serve as an initial indicator of the extent to which digital transformation has the potential to strengthen science learning in schools.

Most existing studies have focused on the general implementation of digital learning without addressing subject-specific needs. The perspectives of science teachers, particularly regarding the integration of digital media in science instruction across diverse regional contexts, have not been adequately explored. This study addresses that gap by presenting large-scale empirical data from junior secondary school science teachers in Indonesia. The novelty of this research lies in its national coverage, its emphasis on the specific pedagogical context of science education, and its contribution to informing evidence-based strategies for digital transformation in science teaching.

In this context, the present study aims to explore junior secondary school teachers' perspectives on the use of digital media and its implications for the transformation of science education in the digital era. The findings are expected to contribute to the development of educational policies, the design of teacher training programs, and the innovation of science instruction that is more relevant to the demands of the digital age.

METHODS

Research Design

This study employed a quantitative approach with a descriptive survey design. The purpose of this design was to explore junior secondary school teachers' perspectives on the use of digital media and its implications for the transformation of science education in the digital era. The descriptive survey design is appropriate for capturing large-scale perceptions, identifying patterns of digital media usage, and understanding teachers' experiences based on measurable indicators.

Procedure

The research process involved several stages: (1) instrument development based on relevant literature and expert input; (2) validation of the instrument by three education and digital learning experts; (3) distribution of the online questionnaire through a national teacher network; (4) collection of responses; and (5) data cleaning and analysis. All stages were coordinated in collaboration with national education stakeholders to ensure relevance and validity. The overall flow of the research process is illustrated in Figure 1.

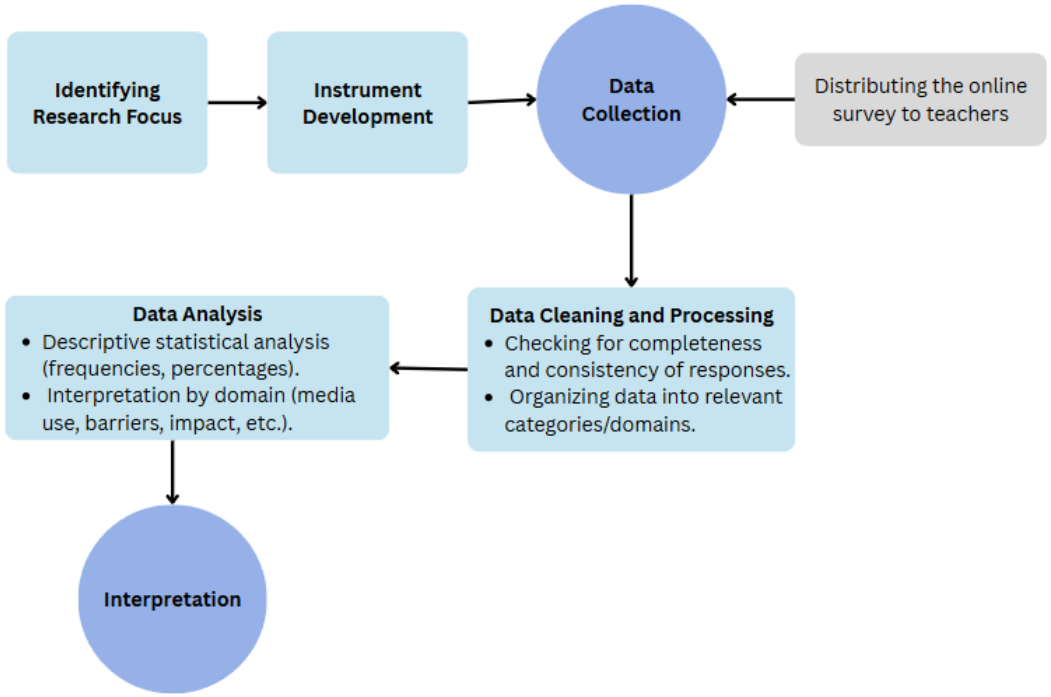

Figure 1. Flow of the Research Process

Participants / Sample

The target population of this study consisted of junior secondary school teachers from various education units across 38 provinces in Indonesia. A total of 1,622 teachers participated in the survey. The sampling technique used was convenience sampling, as participants were selected based on their accessibility and willingness to respond to the online survey distributed nationwide (Golzar et al., 2022).

Instruments

Data were collected using a structured questionnaire consisting of 14 items designed to explore five key domains: (1) intensity of digital media use, (2) types of digital media, (3) implementation barriers, (4) expected support and solutions, and (5) perceived impact on student learning. The questionnaire included both rating-scale and multiple-choice items. The rating scale consisted of four response levels (e.g., never, several times in a week, once a month, daily) and was used to measure perceptions or the intensity of digital media use. Multiple-choice items were used to gather factual data regarding types of

media used, implementation challenges, and anticipated support needs. The instrument covered five domains related to digital media usage, as outlined in Table 1.

Table 1. Domains and Objectives of the Survey Instrument

No.	Domain of Assessment	Sub-domain Description	Type of Items	Measurement Objective	Item Numbers
1	Intensity of Digital Media Use	Frequency of technology integration in classroom instruction	Closed-ended (rating scale)	To measure the intensity of digital media use by junior secondary school teachers	Q1, Q6
2	Types of Digital Media Used	Digital media types used (e.g., digital modules, infographics, learning platforms)	Closed-ended (multiple choice)	To identify the diversity of digital media accessed and utilized in instructional practices	Q3, Q4, Q5
3	Implementation Barriers	Primary obstacles in using digital media (devices, connectivity, training)	Closed-ended (multiple choice)	To uncover key challenges in integrating digital technologies into the school environment	Q7
4	Expected Support and Solutions	Types of support: infrastructure, training, policy interventions	Closed & open-ended	To explore teachers' expectations for institutional support in digital transformation	Q8, Q9, Q11, Q14
5	Perceived Impact on Student Learning	Teachers' perceptions of digital media's effect on motivation and understanding	Closed & open-ended	To evaluate how digital media influences student engagement and learning outcomes	Q2, Q10, Q12, Q13

The questionnaire was validated through expert judgment, involving three experts in educational technology and instructional design. The experts evaluated the instrument for construct relevance, item clarity, and alignment with the research objectives. This content validation ensured that the questionnaire items adequately represented the intended measurement domains. Each expert assessed all 14 items based on three principal aspects: content appropriateness, clarity of wording, and alignment with the research objectives. Each aspect consisted of three indicators and was rated using a four-point Likert scale (1 = not appropriate, 2 = somewhat appropriate, 3 = fairly appropriate, 4 = very appropriate).

The expert ratings were analyzed using the Item-Level Content Validity Index (I-CVI) and the Scale-Level Content Validity Index (S-CVI/Ave). I-CVI was calculated as the proportion of experts who assigned a rating of 3 or 4 to an item. The S-CVI/Ave was obtained by averaging the I-CVI values across all items for each aspect. The results showed that I-CVI values ranged from 0.67 to 1.00, while the S-CVI/Ave values were 0.95 for content appropriateness, 0.93 for clarity, and 0.93 for alignment with objectives. These results indicate that the questionnaire demonstrates good to excellent content validity and is therefore considered feasible and appropriate for measuring teachers' perceptions of digital learning transformation in the context of science education

Data Analysis

The data analysis process involved both quantitative and qualitative techniques. Closed-ended responses were analyzed using descriptive statistics, including frequency and percentage distributions, to identify general trends. Open-ended responses were analyzed through an inductive thematic approach, involving categorization, and theme construction. This analysis aimed to uncover teacher perceptions, experiences, and expectations regarding the use of digital media and its implications for enhancing science learning, particularly in terms of concept visualization, student engagement, and the development of scientific and technological literacy.

RESULTS AND DISCUSSION

The result of analysis responses from 1,622 teachers reveals that the majority of teachers reported being accustomed to using technology in their teaching practices. A total of 87.8% of respondents indicated familiarity, while only 12.2% stated that they were not accustomed to it. This high level of familiarity suggests that digital media usage is no longer foreign to teachers and has become part of their daily pedagogical routines. These findings align with the study by Marisana et al. (2023) which indicated that most junior secondary teachers have experience using various digital platforms to support both online and offline learning activities. However, it is essential not only to examine whether teachers have used digital media but also how frequently it is actually integrated into practice, as illustrated in Figure 2.

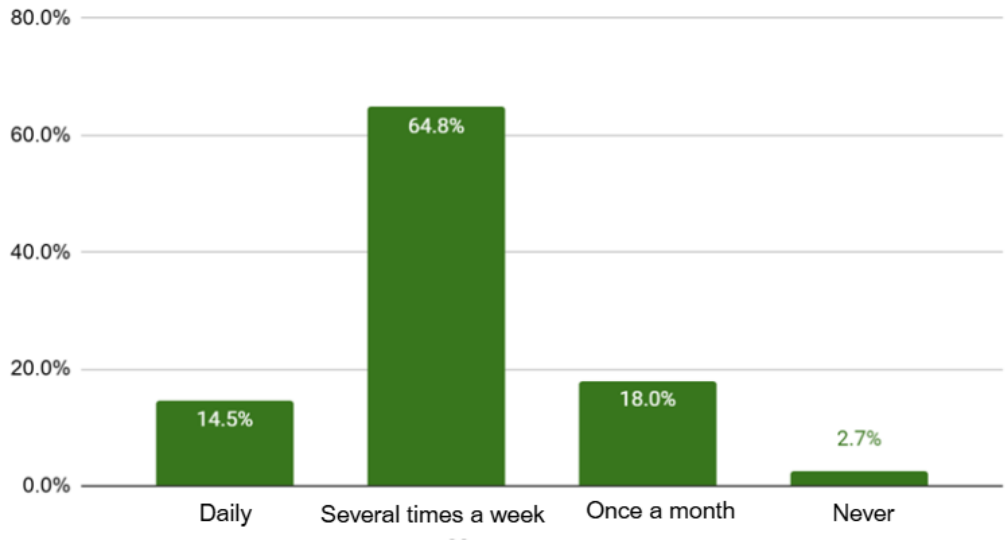

Figure 2. Frequency of Digital Media Use in Learning Activities

As shown in Figure 2, 64.8% of teachers use digital media several times per week, 14.5% use it daily, 18% only once a month, and 2.7% have never used digital media in their teaching. The dominant weekly usage indicates that digital media is used regularly by teachers in lesson planning and instructional delivery. However, the relatively low proportion of daily use (14.5%) suggests that digital media integration in classroom instruction remains partial. This can be attributed to operational constraints such as the availability of devices in classrooms, school infrastructure readiness, and the amount of preparation time required to design digital-based learning materials.

These findings are consistent with the study by (Salam et al., 2023), which reported that although most teachers understand the importance of digital media, its application remains situational, depending on the topic, availability of devices, and technical support at the school level. In the context of science education, consistent use of digital media is crucial, as it supports the visualization of abstract concepts and natural phenomena that are difficult to observe directly. The fact that 18% of teachers only use digital media once a month and 2.7% never use it at all is a noteworthy concern. These figures indicate a gap in the adoption of educational technology, both in terms of access and teacher competency. As stated by (Chai et al., 2013) in the Technological Pedagogical Content Knowledge (TPACK) framework, effective mastery of educational technology is not only related to technical skills but also to pedagogical integration and alignment with content knowledge.

Additionally, the variation in usage frequency may reflect differences in digital literacy levels among teachers. Teachers with higher levels of digital literacy tend to use digital media more frequently and in a more diverse manner (Demirtaş & Mumcu, 2021; Petko, 2012). Therefore, increasing usage frequency should not rely solely on device provision but must also be supported by systematic and continuous programs that strengthen teachers' pedagogical digital literacy.

In general, the data indicate that the digital transformation in education has occurred at the early to intermediate levels of adoption. However, further support is still required to ensure that the use of digital media becomes an integral and consistent component throughout the teaching and learning process. To

achieve a complete transformation, the use of digital media should not be limited to isolated moments but must be embedded within well-planned instructional design aimed at strengthening 21st-century skills, particularly in science education, which often requires visual aids and simulations through various types of digital media.

Teachers employ a variety of digital media. Based on the survey results presented in Figure 3, the most widely used tool was a visual design platform (23.2%), followed by digital presentations (12.5%), digital modules (10.9%), as well as instructional videos and infographics. These findings suggest that teachers tend to select media that are easily accessible, flexible, and adaptable to instructional needs.

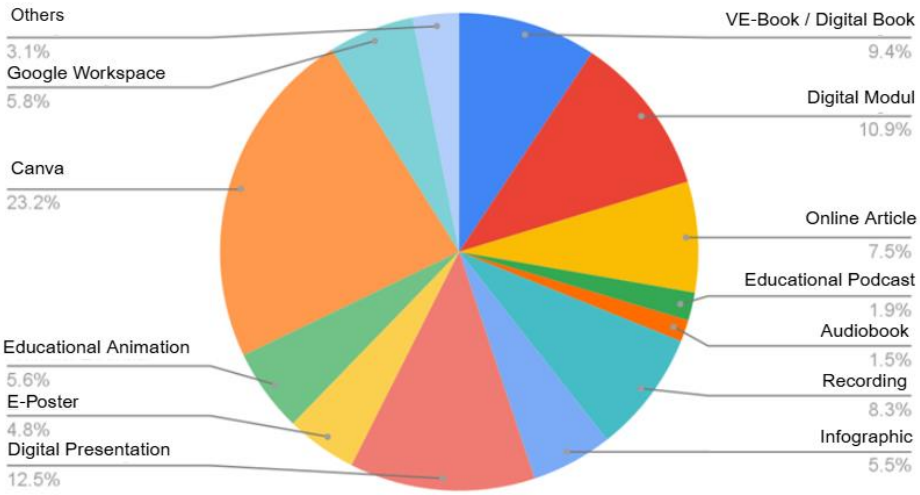

Figure 3. Types of Digital Media Used in the Learning Process

Among the various digital media used, visual design tools—such as infographic or diagram creators—enable teachers to present science content in visually engaging formats, making it easier to explain topics such as the respiratory system, the water cycle, or energy transformations. Digital presentations remain a popular choice due to their simplicity and ease of use. Meanwhile, digital modules support students' independent learning and play a significant role in project-based and inquiry-based science instruction (Al Mamun et al., 2020; Syawaludin et al., 2022)

However, the relatively low utilization of interactive media such as educational animations (5.6%), e-posters (4.8%), and interactive simulations suggests that the development of digital media in science learning has yet to reach its full potential. Teachers tend to use visual media rather than interactive media, which limits students' opportunities to explore scientific concepts. This indicates a gap between the potential of digital media and its actual implementation in science classes. Although teachers are accustomed to using technology and a variety of digital media, they still face numerous barriers to implementation. In addition to presentation and visual media, the use of Learning Management Systems (LMS) is also an important indicator of digitalization in education. According to the survey results, this is further illustrated in Figure 4.

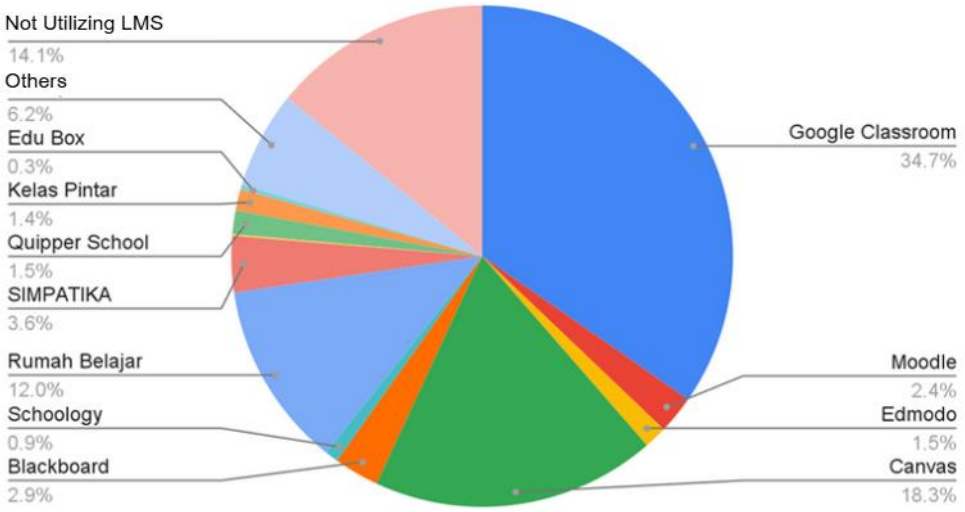

Figure 4. Distribution of Learning Management System (LMS) Use in Learning

Based on Figure 4, the most widely used Learning Management System (LMS) among teachers is Google Classroom (34.7%), followed by Canvas (18.3%) and Rumah Belajar (12%). However, 14.1% of teachers reported not using any LMS at all. This indicates that, despite widespread introduction, significant gaps remain in LMS adoption.

In the context of science education, LMS platforms can serve as integrated tools for distributing digital content such as experiment videos, HOTS-based exercises, and inquiry-based discussion forums. These findings reinforce the study by (Arikarani & Amirudin, 2021) which emphasized that LMSs not only enhance online classroom management but also expand student access to scientific learning resources in a flexible manner. LMS features such as automated assessments and learning material repositories are especially helpful for science teachers in conducting formative assessments and providing project-based enrichment. Nevertheless, the implementation of LMS and other digital media tools does not proceed smoothly across all educational institutions. The uneven adoption and dominance of certain platforms suggest disparities in access and technical readiness between schools and teachers. According to the survey, the various barriers to digital media implementation identified by teachers are presented in Figure 5.

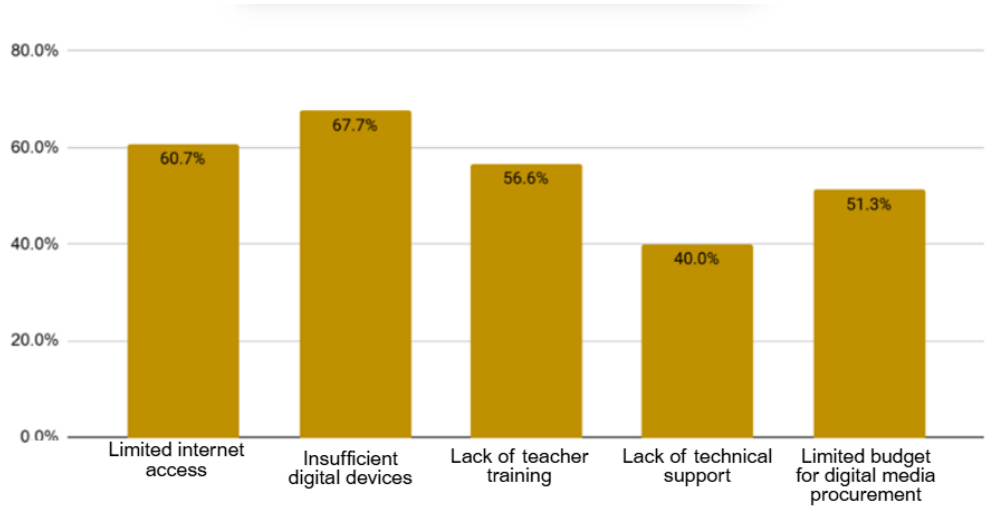

Figure 5. Key Barriers to the Implementation of Digital Media in Learning

Based on Figure 5, the most dominant barrier faced by teachers in implementing digital media is the limited availability of digital devices (67.7%). This high percentage indicates that although teachers are willing to use digital media, they are often constrained by the lack or malfunction of supporting tools such as laptops, projectors, or student devices. In the context of science education, this obstacle is particularly critical, as digital media is often essential to convey abstract phenomena and simulate experiments that cannot be conducted directly in class. This is reinforced by the findings of (Mashami et al., 2023) who noted that limited device access hampers science teachers' use of interactive applications such as virtual laboratory simulations. Internet access limitations (60.7%) represent the second most significant barrier, especially in the use of online learning platforms that rely on streaming or downloading large visual content. For science teachers, this constraint reduces opportunities to present experiment videos, chemical reaction animations, or geoscience phenomena. (Nurmaliah & Nursyamsiah, 2020) highlighted that poor connectivity not only decreases the effectiveness of learning but also reduces students' curiosity and motivation to explore the subject matter.

The lack of training (56.6%) shows that not all teachers have sufficient competence in designing and implementing digital learning optimally. Many available training programs remain focused on basic technical skills without strengthening the pedagogical aspects essential for developing technology-based learning materials. In fact, digital pedagogical training is crucial for equipping teachers with the ability to design interactive and contextual learning experiences, particularly in science subjects that require visual representations, simulations, and inquiry-based approaches. The study by (Mutiara Nabilah & Anwar, 2023), found that science teachers who received content- and pedagogy-based training showed significant improvement in developing interactive modules and digital science learning activities compared to those who only received general technical training.

The absence of digital pedagogical training has led to difficulties in transforming conventional science materials into interactive and meaningful digital formats (Timotheou et al., 2023). This emphasizes the urgency of improving teacher competence not only in technical dimensions but also in science-based instructional design. Budget constraints and the lack of technical support further hinder the digital transformation process in schools. Without funding policies for devices and technical services, teachers will struggle to consistently develop and deliver digital science instruction. In response to these challenges, teachers have also suggested several recommendations that reflect the actual needs to support the success of digital learning transformation, as presented in Figure 6.

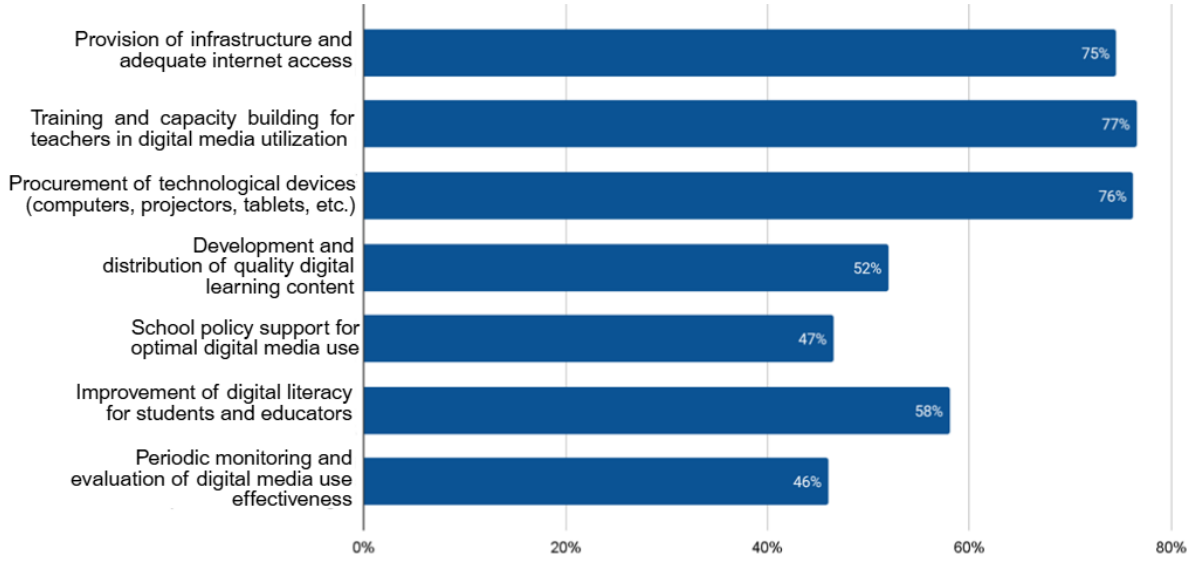

Figure 6. Solutions and Support Expected for The Digitalization of Learning

Nearly all recommendations proposed by teachers in the survey indicated a percentage above 40%, highlighting that the issues raised are urgent and reflect real needs in the field. The high percentages underscore that teachers are not only aware of the importance of providing physical infrastructure but

also emphasize the necessity of strengthening digital pedagogical competencies. In the context of science learning, professional development is highly essential to assist teachers in developing media that can effectively visualize abstract scientific concepts, such as particle motion, chemical reactions, or molecular structures. Without proper training, digital media risk becoming mere passive presentation tools rather than instruments for conceptual representation or scientific inquiry (Clark & Mayer, 2016). The perceived impact of digital media use on students further reinforces the importance of this transformation, as illustrated in Figure 7.

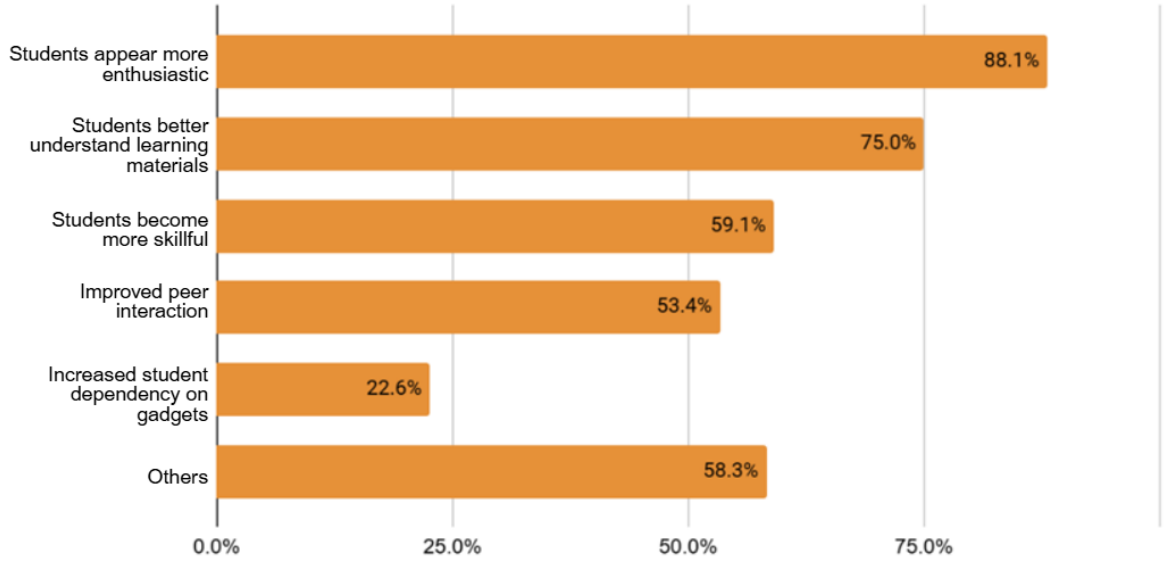

Figure 7. Teachers' Perceptions of The Impact of Learning Digitalization on Students.

Figure 7 indicates that 88.1% of teachers reported increased student enthusiasm, and 75% observed improved understanding. This demonstrates that digital media serves not only as a learning aid but also as a driver of motivation and knowledge construction (Demirtaş & Mumcu, 2021; Nurdini et al., 2018). In science education, student enthusiasm is especially crucial as it fosters exploration, observation, and experimentation—whether conducted physically or through virtual simulations.

These findings are consistent with the study by (So et al., 2019b) which revealed that teacher training in the development of interactive media has a direct impact on improving learning quality, especially in science subjects that require digital visualizations and experiments. Moreover, (Mutiara Nabilah & Anwar, 2023), found that science teachers who participated in TPACK-based training were more capable of presenting complex content through relevant digital media, such as chemical reaction simulations, interactive models of the human body system, and visualizations of physical laws.

Survey data also indicated that 85.6% of teachers stated that training in the use of digital media is highly important. This supports the argument that teacher capacity is a fundamental pillar in the transformation of digital science learning, as teachers act not only as information deliverers but also as facilitators of scientific thinking through digital exploration. In line with this, 81.6% of schools expressed a strong interest in joining mentoring programs on digital media use. This high enthusiasm reflects institutional awareness of the importance of mentoring as part of human resource capacity development. In science learning, mentoring can be directed toward the development of virtual science labs, the implementation of digital inquiry-based approaches, and the integration of augmented reality for observing natural phenomena.

The readiness for implementing digitalization is also reflected in schools' preparedness to adopt digital learning platforms. As many as 59.4% of schools stated they would definitely use free digital platforms, and 39.5% indicated they would use them with mentoring. This suggests that school-level institutional commitment is relatively strong, although practical guidance is still needed. Such readiness serves as a critical foundation for the success of science learning transformation, which demands integration across curriculum, pedagogy, and technology.

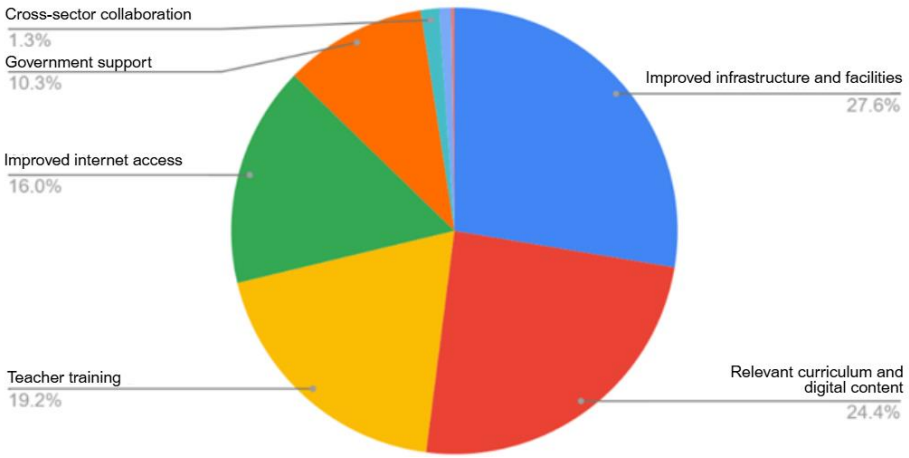

Figure 8. Teachers' Expectations for Digitalization Learning in Schools

Figure 8 illustrates that teachers hold high expectations for improvements in infrastructure (27.6%), digital curriculum and content (24.4%), and teacher training (19.2%) as key factors for successful digitalization. In the context of science education, a curriculum that adapts to digital media enables the development of phenomena-based learning, problem-based learning, and technology-integrated inquiry approaches. This is in line with (van Laar et al., 2020), who emphasized the need for a science curriculum that is responsive to digital contexts and 21st-century skills.

CONCLUSION AND SUGGESTION

Based on the analysis of survey data from junior high school teachers regarding the use of digital media in teaching, it can be concluded that the transformation of learning in the digital era has shown a positive trend. This is indicated by the increasing frequency and variety of digital media used in classrooms. Teachers have utilized various types of media, such as educational videos, digital presentations, and learning management systems, although their use is still uneven and tends to be presentation-focused. In the context of science learning, digital media have not yet been fully optimized as exploratory tools to explain abstract concepts and to develop students' scientific skills. Several challenges remain, including limited access to devices and internet connectivity, a lack of training in digital pedagogy, and insufficient technical support and funding. These findings offer practical implications for key stakeholders: (1) policymakers are expected to design inclusive digital transformation policies that consider infrastructure gaps and subject-specific needs; (2) teachers need continuous, subject-based professional development programs that integrate digital tools into pedagogical practices; and (3) training developers should design context-relevant and adaptive training modules to support teachers' digital competencies in science education. Furthermore, it is essential to build a collaborative and adaptive learning ecosystem that keeps pace with technological advances so that digital transformation represents not merely a change of tools but a genuine paradigm shift toward more scientific, participatory, and meaningful learning experiences for students.

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