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Integration of Digital Media in the Discovery Learning Model to Enhance Junior High School Students Conceptual Understanding in Science: A Review

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Abstract: The low level of students' conceptual understanding in science learning remains a primary issue, as instructional activities often emphasize rote memorization and fail to optimally utilize digital media to support meaningful learning. This study aims to examine the role of digital media across the stages of the Discovery Learning model, identify the most effective types of digital media, and determine the characteristics of science topics that require technological support. The research method employed is a Systematic Literature Review (SLR) of 15 relevant articles published between 2020 and 2025. Data were analyzed thematically by grouping findings based on the role of digital media in the Discovery Learning stages, media types, science topics, as well as supporting and inhibiting factors in implementation. The results indicate that digital media such as PhET simulations, animated videos, interactive flipbooks, and augmented reality significantly enhance students' conceptual understanding by providing visual and interactive representations. These media are most effective for abstract topics such as energy, the solar system, and the digestive system. However, their implementation faces challenges, including limited school facilities, low digital literacy among teachers and students, and insufficient preparation time. The integration of digital media within the Discovery Learning model proves effective in concretizing abstract science concepts, with the novelty of this study lying in its comprehensive mapping of the relationships between media types, learning stages, and topic characteristics. Practically, these findings can serve as a guide for educators in selecting and designing digital media for more innovative instruction. Academically, this study encourages further research to address implementation challenges and to explore more personalized and adaptive technology integration for supporting quality science education.

Keywords: Digital Media; Discovery Learning; Science Concept Understanding.

Introduction

Education is a system consisting of various interconnected elements aimed at achieving common goals (Masayu). Its main elements include processes, efforts, and outcomes. A well-functioning educational system is key to achieving targets [1], [2]. The goal of modern education is for learners to understand concepts deeply, not merely to memorize. In science education, this shift is evident as the focus has moved from a model of knowledge transmission to an approach that emphasizes the development of higher-order cognitive skills [3]. However, in reality, many learners still view science education merely as a subject to study. Learning that emphasizes memorization strengthens theoretical knowledge but weakens application skills. Consequently, innovation and exploration decrease [4].This condition shows that science learning needs to be optimized by considering several important components, such as the teacher's role in formatting concepts meaningfully and learners' readiness to process and apply information. The effectiveness of science learning is measured by learners' ability to construct meaningful knowledge. Recent research also emphasizes the importance of learners' active role in understanding concepts. Therefore, mastery of science concepts must be continuously improved, not just limited to knowing facts, but also being able to explain and apply them in daily life [5].

Curriculum serves as the primary guide in achieving national education goals and is flexible to adapt to the developments of the times [6]. The current Indonesian curriculum implements the *Deep Learning* principle, which emphasizes meaningful learning, meaning that learners understand concepts deeply and can apply them in daily life, not merely memorize [7]. Deep Learning contrasts with Surface Learning, which focuses solely on memorization, because it encourages learners to think critically and develop Higher Order Thinking Skills (HOTS) [8]. This curriculum aligns with the Discovery Learning model, which guides learners to discover and construct concepts independently [9]. Science learning needs to be continuously improved so that learners not only know facts but can also explain and apply concepts in daily life.

The Fifth Industrial Revolution provides great potential for implementing Discovery Learning with support from *IPTEK*-based digital media. Digital media is a technology-based tool that can assist the learning process by presenting information interactively and attractively. Digital media can be utilized to help learners understand material, solve problems, and build conceptual understanding through more meaningful learning experiences [10]. Currently, digital media is widely used

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in daily life, such as online learning applications, interactive learning videos, virtual simulations, and digital quiz platforms, which help human work become faster and more efficient and produce better learning outcomes [11]. The utilization of digital media can support the learning process by assisting teachers in explaining concepts interactively and contextually. Digital media, such as learning videos, interactive simulations, digital quizzes, or visual materials, can facilitate students who have difficulty understanding concepts by providing additional explanations tailored to their needs [12]. This media does not replace the teacher's role but rather strengthens the teacher's ability to deliver material effectively and adaptively. With appropriate support from digital media, learners' conceptual understanding can improve because explanations are presented in varied ways and tailored to each student's learning style.

The Discovery Learning model is often chosen to facilitate strong knowledge construction and achieve solid conceptual understanding. Discovery Learning essentially emphasizes the independent discovery of concepts. Discovery Learning is a teaching method focused on independent discovery that falls under inquiry-based learning and is aligned with constructivism, which posits that learners construct their own knowledge [13]. This model falls under inquiry-based learning and is considered a constructivist learning approach, meaning that Discovery Learning is supported by theorists who believe that learners learn best by constructing their own knowledge. Hypothesis test results statistically show that the Discovery Learning model has a significant effect on learners' understanding of mathematical concepts, as evidenced by a statistical test value of 5.248 which is much greater than the critical value of 2.080, and a significance value of 0.000 which is smaller than 0.05 [14]. Practically, there is a significant increase in learners' conceptual understanding, evidenced by the substantial rise in average scores from 54.70 before treatment (pre-test) to 71.91 after applying Discovery Learning (post-test). However, in practice, teachers still often face difficulties providing scaffolding that truly fits each learner's needs, especially when learners must analyze complex data.

A review of previous studies shows a research gap. On one hand, digital media is often utilized as a tutor for directly completing exercises and quizzes, which results in a predominantly instructional approach that does not fully scaffold learners' thinking processes[15]. On the other hand, the use of digital media that emphasizes visualization aspects still cannot provide guidance that accommodates differences in learners' understanding levels and tends to be static because it cannot "think along" with learners in the learning process [16]. Therefore, to date, no research has specifically explored and synthesized the application of digital media in the Discovery Learning model to support the development of learners' conceptual understanding in science. Thus, this literature study aims to fill this gap by mapping the role of digital media, analyzing its impact, and identifying various challenges that may arise in its application to science learning based on Discovery Learning.

Research Methods

Research Design

The method used in this study is Systematic Literature Review, which involves reviewing existing research on a specific topic by collecting, evaluating, and selecting relevant studies, then drawing conclusions based on predetermined criteria [17]. A Systematic Literature Review (SLR) was chosen as one of the approaches employed in this research. The Systematic Literature Review (SLR) approach is a research method aimed at identifying, reviewing, evaluating, and understanding existing research findings related to a particular topic or phenomenon [18]. The research design is adapted from the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) model by [19]. The literature used consists of studies or research results published in journals. The literature selection process is illustrated in the following scheme:

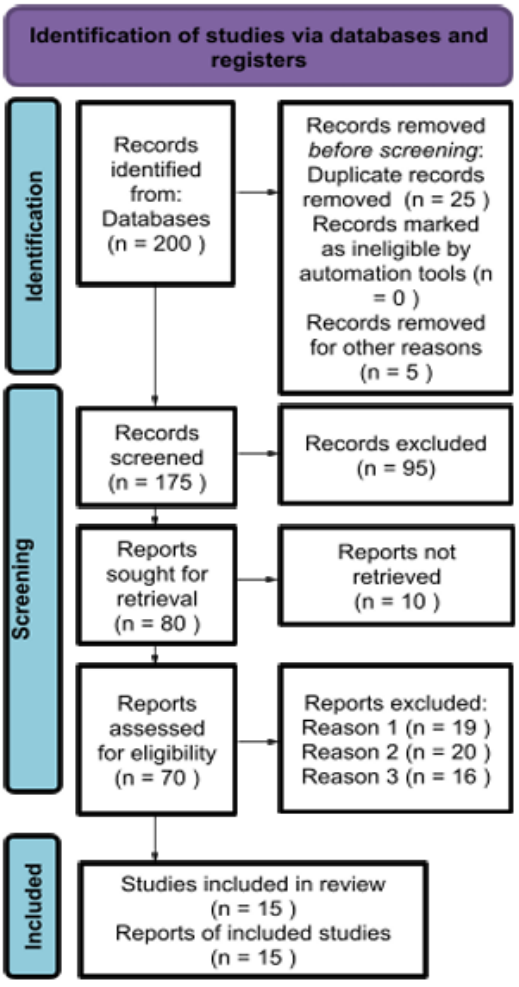

Figure 1. PRISMA Flow Diagram

Research Targets

The research was conducted from October to December 2025, targeting 15 journals published between 2020 and 2025 that addressed AI-based Discovery Learning and its effects on conceptual understanding in

science. The electronic literature search was conducted using Google Scholar, assisted by PoP 8 (Publish or Perish 8).

Data Collection Techniques

The data collection in this study consisted of several stages, including identification, screening, eligibility, and inclusion. The identification stage determines the topic and research questions and searches for literature through electronic databases. The research questions obtained include RQ1: Which digital media are most effective in supporting the stages of Discovery Learning to enhance learners' conceptual understanding in science? RQ2: Which science materials are suitable for the use of digital media in Discovery Learning? RQ3: What are the inhibiting factors in the implementation of digital media in the Discovery Learning model in SCIENCE learning?

Table 1. Inclusion and Exclusion Criteria

Aspect	Inclusion	Exclusion
Research Topic	Articles discussing Discovery Learning combined with AI technology in SCIENCE learning.	Articles not relevant to Discovery Learning, not related to AI, or not discussing SCIENCE learning.
Study Scope	Within the context of education (especially SCIENCE education).	In professional fields outside education, such as medicine, health, socio-cultural studies, engineering, or other non-educational areas.
Publication Period	Published between 2020–2025.	Published before 2020.
Language	Written in Indonesian or English.	Written in languages other than Indonesian or English.
Publication Type	Published journal articles.	Literature other than journals.
Journal Credibility / Indexing	Indexed in SINTA 1–4, Scopus, or other credible scientific databases.	Not indexed in SINTA or Scopus, or in predatory journals.
Accessibility (Full Text)	Full-text articles available and accessible.	Only abstracts or partial content available and difficult to access.

The literature search was conducted using Google Scholar and assisted by PoP 8 (Publish or Perish 8), resulting in 200 articles published between 2020 and 2025 using the keywords "Discovery Learning", "*Media Digital*", and "*Pemahaman Konsep IPA*". The second stage was screening, during which articles deemed irrelevant based on title, abstract, and topic suitability were removed, resulting in 200 articles. The eligibility stage involved selecting literature based on inclusion and exclusion criteria. The inclusion and exclusion criteria for this study are shown in Table 1.

After screening the articles according to the inclusion and exclusion criteria, the next stage is to review or analyze the filtered articles, which consist of 15 articles.

Results and Discussion

Time Distribution

This study synthesizes findings from 15 articles published between 2020 and 2025 to address several research questions, including RQ1: Which digital media are most frequently used in Discovery Learning to enhance learners' conceptual understanding in science? RQ2: What are the characteristics of materials that require digital media in Discovery Learning for science learning? RQ3: What are the inhibiting factors in the implementation of digital media in the Discovery Learning model for science learning? To answer these three main research questions, this discussion focuses on: (1) identifying the most frequently used digital media in Discovery Learning to improve learners' conceptual understanding in science; (2) determining the characteristics of science materials that require support from digital media; and (3) mapping the facilitating and inhibiting conditions in the implementation of digital media within the Discovery Learning model. Based on these three focuses, the discussion is directed toward reviewing the dominant types of digital media used in the Discovery Learning stages, identifying the science materials most relevant to their use, and mapping the conditions that facilitate or hinder their success. These three aspects provide a comprehensive overview of the patterns of digital media utilization in Discovery Learning that can improve learners' conceptual understanding in science, based on studies published in the last five years.

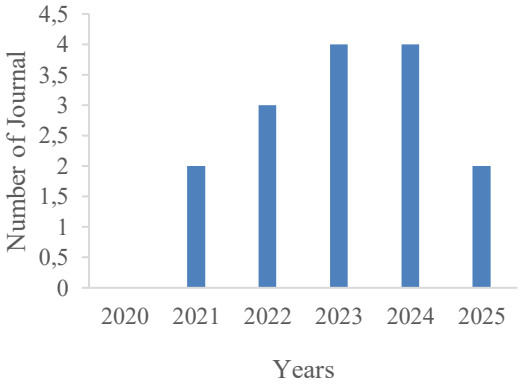

Figure 2. Frequency of journals discussing digital media in the Discovery Learning model

Figure 2 shows the number of journals discussing digital media in the Discovery Learning model during the period from 2021 to 2025, totaling 14 articles. The publication pattern appears to fluctuate: in 2021, there were two journals, increasing to three in 2022, then peaking in 2023 and 2024 with four journals each year. After that, the number declined again to two journals in

2025. This pattern indicates that the topic of digital media in Discovery Learning continues to attract researchers' attention but does not show a consistently increasing trend. The rise in 2022–2023 indicates a temporary increase in interest, whereas the decline in 2024–2025 suggests a shift in research focus. This condition may be due to the growing popularity of other topics such as AI, AR, and gamification, which attract more researchers [20], as well as the perception that Discovery Learning is a model that has been long used, leading researchers to shift toward more contemporary models like STEM and Deep Learning [21]. In addition, limitations in school digital facilities have prevented significant research on digital media in junior high schools [22].

Highly Cited Articles

Given the fluctuating research trends shown in the previous figure, a deeper understanding of the direction and quality of research on digital media in Discovery Learning is required. This condition requires a deeper understanding of the topic to clarify the research direction and quality. Publication count alone does not fully indicate the development of this topic, so it is also important to examine highly influential articles. Highly cited articles usually contain ideas or findings that are significant for subsequent research. By reviewing these articles, I can identify the main trends and determine which areas remain underexplored. This helps me understand why research on digital media in Discovery Learning needs to address RQ1, RQ2, and RQ3.

Table 2. Highly Cited Articles

No	Title	Authors	Journal	Year	Citation
1	Development of flipbook-based digital media to enhance students' critical thinking skills	Riska Dwi Prasasti dan Nirwana Anas	Munaddhomah: Journal of Islamic Education Management	2023	77
2	Implementation of PhET simulation with Discovery Learning model to improve understanding of dynamic electricity concepts	Vera Meidy Anisa and Dyah Astriani	*Jurnal Pijar MIPA*	2022	31
3	A systematic literature review: the effect of augmented reality-based learning media on students' conceptual understanding and learning interest	Vandan Wiliyanti, Siti Nur Ayu, Hendri Noperi, and Yani Suryani	BIOCHEPHY: Journal of Science Education	2024	30

Based on the assessment in Table 2 (Most Frequently Cited Learning Media Articles), these studies collectively support the development of digital media as a tool to improve the quality of science learning. "Development of flipbook-based digital media to enhance students' critical thinking skills" is the most frequently cited article in this review, having accumulated 77 citations [23]. This study demonstrates that flipbook media can facilitate learners' development of critical thinking skills through interactive, engaging material presentation, making it relevant to addressing RQ1 regarding digital media that effectively supports the stages of Discovery Learning.

Next, the article "Implementation of PhET simulation with Discovery Learning model to improve understanding of dynamic electricity concepts" ranks second with 31 citations [24]. The findings of this study confirm that the use of PhET simulations specifically enhances understanding of dynamic electricity concepts through more concrete learning experiences, thereby providing insight into science materials suitable for digital media within the Discovery Learning model (addressing RQ2).

The article "A systematic literature review: the effect of augmented reality-based learning media on students' conceptual understanding and learning interest" ranks third with 30 citations [25]. This study highlights the role of augmented reality (AR) in improving learners' conceptual understanding and learning interest, while also emphasizing the importance of considering factors that may hinder the implementation of digital media, such as teacher readiness and classroom infrastructure, making it relevant for discussing RQ3. Together, these three articles provide a strong empirical foundation for answering research questions about the effectiveness of digital media, the suitability of science materials, and the inhibiting factors in implementing a digital media-based Discovery Learning model.

Results of Article Analysis

Based on Table 3 (results of article analysis), the answers to the three research questions, namely RQ1, RQ2, and RQ3, are evident. For RQ1, digital media such as interactive multimedia, instructional videos, virtual simulations, and digital quizzes effectively support the stages of Discovery Learning, thereby enhancing learners' conceptual understanding in Science. For RQ2, Science topics suitable for digital media include subjects that require visualization, such as potential and kinetic energy, the solar system, and changes in matter states. Meanwhile, RQ3 highlights several inhibiting factors, including limited facilities, teacher readiness, students' digital literacy, and limited time to design technology-based learning. These findings provide a general overview of the

effectiveness, material suitability, and challenges in implementing digital media in science learning.

Table 3. Table Results of Article Analysis

No	Author	Sample / Research Setting	Research Method	Subject	Digital Media	Key Findings
1	[23]	20 articles	Systematic Literature Review (SLR)	SCIENCE	Interactive multimedia	T-test results (19.482 > 2.045) showed improvement in conceptual understanding. Advantages: visualizes abstract concepts, more interactive and collaborative.
2	[26]	24 seventh-grade students at MTS Al-Wasliyah 2 Kisaran	Classroom Action Research (PTK), qualitative (observation & interview) and quantitative (questionnaire & test)	Energy	PhET Simulation	Cycle I: 66.1% mastery, Cycle II: 83.33% mastery, showing improvement in learning outcomes.
3	[27]	30 students in classes VII-A and VII-C SMP Negeri 1 Suwawa, odd semester 2023–2024	Quantitative (true experimental) with Pretest-Posttest Control Group Design	Energy Changes in Life	PhET Simulation	Control class N-Gain: 0.51 (moderate), experimental class: 0.78 (high). Effect size in experimental class: 1.51 (strong), especially C4 skills. Significant improvement in student learning outcomes.
4	[28]	210 students, VIII-4 SMP Negeri 13 Medan, 7 classes, 31 students each	Quantitative, One-Group Pretest-Posttest Design	Pressure	PhET Simulation	Increased learning outcomes; mean score rose from 28.5 (pretest) to 70.17 (posttest). T-test (16.11 > 2.04) and linear regression y = 27.32 + 0.62X indicate significant effect.
5	[24]	Class IX-A (21) & IX-B (20), IJHS Al-Islahiyah Sukobendu Lamongan, 2021–2022	Quantitative, One-Group Pretest–Posttest Design, analyzed via N-Gain, normality, homogeneity, t-test	Digestive System	PhET Simulation	N-Gain IX-A: 0.68, IX-B: 0.66, showing improved conceptual understanding.
6	[29]	36 students, XI MSCIENCE 1 SMA Negeri Samarinda, Nov–Dec 2021	Quantitative, pre-experimental (One-Shot Case Study)	Elasticity & Hooke's Law	PhET Simulation	Concept mastery is moderate for C2–C4, low for C5, and very low for C6. Advantages: helps understand abstract material, increases activity. Challenges: students unfamiliar with virtual lab, unstable connection, and limited supervision.
7	[30]	33 students, VIII SMP Negeri 7 Muaro Jambi, Feb–Mar 2023	R&D ADDIE model; qualitative (questionnaire) & quantitative (pretest-posttest)	–	Animated video	N-Gain mean: 0.79 (high). 24 students high, 5 moderate, 4 low. Barriers: student absence, paid app.
8	[31]	120 students: 47 SD 1 Penarukan, 16 SD 3 Pengelatan; control: 33 SD 4 Penarukan, 24 SD 1 Pengelatan	Quasi-experimental, pre-tests & post-tests	Science and Social	Kahoot	Increased learning interest (0.012 < 0.05) and learning outcomes. Provides immediate feedback, competitive learning, and increased participation. Challenges: teacher/student tech

						skills, planning, distractions, and uneven school facilities.
9	[32]	31 students, VIII SMP Negeri 1 Tombulu, experiment VIII-A (16), control VIII-B (15)	Quasi-experimental, pretest-posttest	Human Respiratory System	Wordwall	N-Gain: 0.72 (high), 72.45% effectiveness. Advantages: student enthusiasm, active discussion, and quick understanding of concepts.
10	[33]	30 students, VIII-J UPT SPF SMP Negeri 19 Makassar (15 male, 15 female)	Classroom Action Research (PTK) 2 cycles	Science	Wordwall	Learning motivation increased from 23.33% in cycle I to 63.3% in cycle II.
11	[34]	41 students, IV SD Negeri 21 Pemecutan (21 male, 20 female)	Classroom Action Research (PTK) 2 cycles	Science	PPT	Mean score increased from 62.80 to 75.85; mastery from 46.34% to 82.93%. Factors: active concept discovery, engaging media, teacher motivation, and online learning support. Challenges: student reluctance to speak, unstable signal, lack of focus, and Google Classroom access.
12	[35]	31 students, VIII-A SMP Semen Gresik (20 male, 11 female)	Pre-Experimental, One-Group Pretest-Posttest	Digestive System	Animated Video	Learning improvement: low 4.16%, moderate 38.7%, high 57.14%. Positive student response: 82.7% of students responded well, showing that Discovery Learning increases engagement and understanding.
13	[36]	VII-A & VII-B MTs Maarif Ambulu	Quasi-Experimental, Posttest-Only Control Group Design	Environmental Pollution	E-book	Scientific attitude improved: experiment mean 80.50 vs. control 69.67; questionnaire: 70.37 vs. 68.64; scientific performance very good, up to 96.67.
14	[37]	60 students, SMP Negeri 2 Sungguminasa, 2 classes of 31	Quantitative descriptive	Solar System	AR & VR	Problem-solving skills varied: highest in problem completion (45.2%), planning (14.9%) & evaluation (9.6%), lowest. Solar System topic: planning (39.9%), identification (33.3%) higher; completion (15.2%) & evaluation (11.6%) still low, need improvement.
15	[38]	34 students, VII-C SMP 26 Semarang, 2022/2023, 21 male, 13 female	Classroom Action Research (PTK) 2 cycles	Solar System	Digital Module	N-Gain: 0.72 (high), cycle II mean: 90.91. Cycle I challenge: students understood Solar System components only through sketches, not in depth.

Most Frequently Used Digital Media in Discovery Learning

Based on Figure 3 (The frequency of digital media used in Discovery Learning based on the articles), the analysis of 15 articles shows that PhET Simulation is the most effective digital media for supporting the stages of Discovery Learning in science education. Its effectiveness is demonstrated by consistent improvements in students' conceptual understanding across multiple studies. Furthermore, PhET Simulations serve as an effective learning medium that not only enhances learning outcomes and student ICT literacy but also enables learning without a physical laboratory, is easy to use within the context of science topics, and supports independent learning outside of school [39]. Significant mastery improvement in the topic of energy was reported [26]. Strong conceptual gains were also demonstrated through a high N-Gain in the experimental class [27]. One study reports an increase in average scores from 28.5 to 70.17 [28]. Another study provides further evidence of improved understanding of the digestive system topic [24]. Improved student engagement in learning elasticity and Hooke's Law was reported [29]. These findings show that PhET supports all stages of Discovery Learning by providing simulations that allow students to explore, manipulate variables, and test ideas independently. As an interactive virtual lab, it further enhances science education by improving cognitive outcomes, offering ease of use and flexibility, and

transforming abstract concepts into tangible visualizations [40].

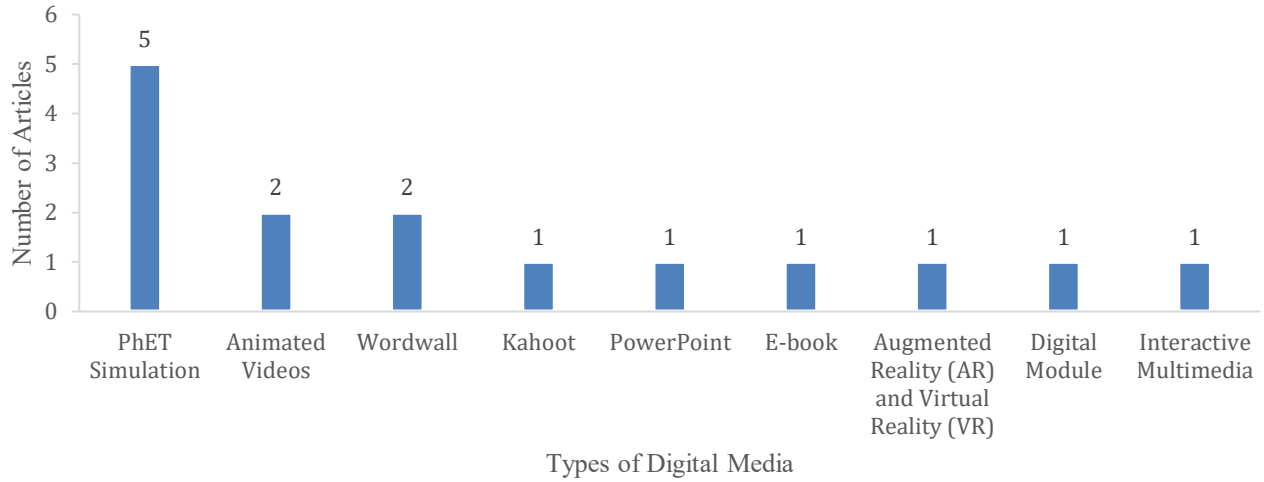

Figure 3. The frequency of digital media used in Discovery Learning is based on the articles

Several other digital media tools are also effective at specific stages of Discovery Learning. The effectiveness of animated videos in supporting the stimulation and data collection stages by simplifying and visualizing scientific processes has been demonstrated [30], [35]. Moreover, animated videos developed on the discovery learning model offer additional pedagogical advantages by enhancing students' critical thinking through problem-based scenarios that stimulate curiosity and by utilizing audio-visual elements that facilitate independent comprehension, as evidenced by product trials that yielded excellent qualifications [41]. Wordwall contributes significantly to the verification and generalization stages by helping strengthen concept mastery through interactive quizzes [32], [33]. Additional media, such as Kahoot, also support students' exploration and concept processing [31]. Similarly, tools such as PowerPoint, e-books, augmented reality, and digital modules provide support based on the technological conditions in each school [34], [36], [37], [38]. Based on all findings, it can be concluded that PhET Simulation is the most effective digital media for supporting Discovery Learning and improving conceptual understanding in science because it allows independent exploration and provides a clear visualization of abstract content. However, animated videos, Wordwall, Kahoot, and other multimedia tools still play important complementary roles in specific stages of the model. Using a combination of digital media that aligns with the material's characteristics and students' needs can create more meaningful Discovery Learning experiences and lead to stronger conceptual understanding in science.

Characteristics of Science Materials Requiring Digital Media Support

Based on Figure 4 (The number of Science topics covered using digital media in Discovery Learning), the findings from the fifteen reviewed studies indicate that the implementation of digital media within the Discovery Learning model is most intensively applied to science materials that involve abstract concepts, invisible processes, and phenomena requiring dynamic visualization. Based on the distribution of subjects, Energy, the Digestive System, and the Solar System are the most frequently used materials, each appearing in two studies. Energy shows consistent learning improvement when supported by interactive simulations, as demonstrated by one study where the use of PhET Simulation increased mastery from 66.1% in Cycle I to 83.33% in Cycle II [26]. This finding is reinforced by a systematic literature review, which confirms that interactive multimedia is highly effective in visualizing abstract scientific concepts and improving students' conceptual understanding [23]. These results confirm that energy is one of the most dominant and suitable topics for Discovery Learning supported by digital media, given its abstract nature and reliance on conceptual transformation.

In biological science, the Digestive System emerges as a dominant topic where digital visualization facilitates strong learning gains, demonstrated by moderate-to-high N-Gain values (0.68 and 0.66) following PhET Simulation implementation [24]. Similarly, one study found that 57.14% of students achieved high learning improvement with the use of animated video, and more than 90% of students gave positive responses to the learning process [35]. These findings indicate that materials from the digestive system, which involve internal organ functions that cannot be directly observed, are highly compatible with digital animation and simulation within the Discovery Learning stages of stimulation, data collection, and verification.

Astronomy-related content, particularly Solar System content, consistently benefits from digital media integration. One study, for example, reported that AR and VR media supported problem identification and planning skills, especially in spatial visualization of planetary motion, although evaluation skills still required improvement [37]. This finding is complemented by a high N-Gain score of 0.72 and a Cycle II mean score of 90.91 achieved after implementing a digital module [38]. These results indicate that the Solar System is a highly suitable topic for digital-based Discovery Learning because it demands spatial reasoning and visual

representation that cannot be experienced directly in the classroom.

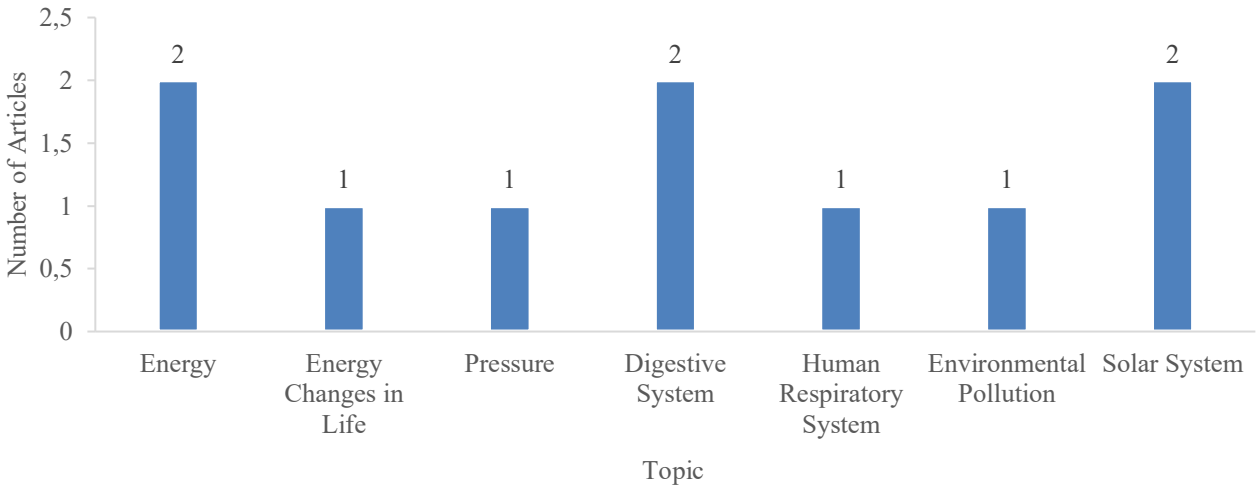

Figure 4. The number of Science topics covered using digital media in Discovery Learning

Other materials appear less frequently but still demonstrate meaningful learning impacts. Energy Changes in Life, which appears in only one of the reviewed studies, also shows strong effectiveness. In the experimental class, students achieved a high N-Gain of 0.78 and a strong effect size of 1.51, with notable improvement in C4 cognitive skills [27]. This indicates that although it appears less frequently, this topic still holds strong potential when supported by digital simulation. A substantial learning increase was observed in the topic of Pressure, where mean scores rose from 28.5 in the pretest to 70.17 in the posttest, a result supported by a significant t-test and regression analysis [28]. This confirms that pressure material benefits from interactive manipulation that allows students to explore the relationship between force, area, and pressure.

In the biological domain, the Human Respiratory System achieved a high N-Gain of 0.72 with an effectiveness level of 72.45% when taught using Wordwall [32]. The interactive and game-based features of the platform were found to increase student enthusiasm and accelerate conceptual understanding [42]. Meanwhile, Environmental Pollution also showed strong improvement in scientific attitudes and performance through the use of e-books, with experimental class performance reaching up to 96.67% [36]. This indicates that environmental topics are well supported by digital media that model cause-and-effect relationships.

Overall, these findings confirm that science materials most suitable for digital media integration within the Discovery Learning model are those that require visualization, interaction, sequential processes, and abstract conceptualization. Dominant topics such as Energy, the Digestive System, and the Solar System consistently demonstrate strong learning gains, while other topics such as Energy Changes in Life, Pressure, the Human Respiratory System, and Environmental Pollution also show positive impacts despite appearing less frequently. Digital media supports students' exploratory processes, promotes active engagement, strengthens reasoning, and helps construct deeper conceptual understanding across diverse science domains.

Inhibiting Factors in Implementing Digital Media in Discovery Learning

The analysis of the fifteen studies reveals a range of inhibiting factors that limit the effectiveness of digital media implementation within the Discovery Learning model for science learning. One of the most frequently reported obstacles is unstable or limited internet connectivity, which significantly disrupts the use of digital platforms, virtual laboratories, and interactive applications [43]. This issue appears clearly in studies utilizing PhET Simulation. Many students struggled to operate virtual laboratory features because weak internet connections caused delays, loading errors, and interruptions during simulation activities [29]. These disturbances prevented learners from exploring elasticity concepts effectively during the data collection and verification stages of Discovery Learning [44]. Similar findings were documented in a study that used Google Classroom to support concept discovery activities [34]. Similar findings were documented in a study that used Google Classroom to support concept discovery activities, which reported that unstable internet access and limited platform usability reduced student engagement and hindered effective participation in learning tasks, causing learners to miss essential stages of the learning process [45]. Their study highlighted that unstable signal quality and limited internet access reduced student participation, with many learners unable to submit assignments or follow digital instructions in real time. These connectivity challenges directly disrupt the core inquiry processes of Discovery Learning, where students must continuously interact with digital media to observe patterns, test hypotheses, and verify scientific ideas.

In addition to technical connectivity issues, the studies also indicate that the digital literacy and technological competencies of both students and teachers play a crucial role in determining the success of digital media integration. The study explicitly noted that many students were unfamiliar with virtual laboratory environments, resulting in confusion and hesitation when manipulating simulation variables [29]. This issue was compounded by limited device access, unstable internet

connectivity, and the need for teacher guidance in using PhET simulations, indicating that successful implementation depends heavily on adequate infrastructure and teachers' technological competence [46]. This lack of familiarity reduced the depth of exploration and prevented students from engaging with higher-order inquiry tasks. The implementation of Kahoot in science and social studies revealed that insufficient technical skills among teachers and students led to inefficient class management and reduced the potential benefits of the platform's competitive learning features [31]. This situation is exacerbated by the low level of teacher digital competence, where, despite over half using digital devices daily, approximately 44% still lack the skills to create ICT-based learning media or evaluation instruments, leaving their mastery limited to basic communication tools rather than the complex educational applications or LMS platforms necessary to foster students' critical and creative thinking [47]. Some learners required repeated guidance to log in, interpret questions, or respond effectively due to low digital proficiency. Furthermore, poor planning and classroom management occasionally resulted in distractions, such as students accessing unrelated digital content. These findings show that without adequate digital skills, simulations, quizzes, and multimedia tools cannot fully support the stages of problem identification, hypothesis formulation, and conceptual verification in Discovery Learning.

Resource limitations also emerge as significant inhibiting factors. Several studies emphasize unequal access to facilities, paid applications, and limited teacher supervision as barriers to effective digital learning [48]. The development of animated videos for science learning faced a challenge when the selected application required a subscription, which prevented some students from fully accessing all the features necessary for exploration and concept reinforcement [30]. This payment barrier reduced uniformity in learning experiences and hindered the intended discoverybased approach. This is consistent with the digital divide literature, which indicates that unequal access to digital technologies, including internet costs, limited availability of adequate devices, and infrastructural constraints, constitutes a major barrier to the full utilization of digital learning media, thereby reducing students' opportunities to independently access and explore learning features and ultimately diminishing the effectiveness of discovery-based learning approaches [49]. Infrastructure inequality was also observed, characterized by differences in school facilities such as variable device availability, inconsistent classroom technology, and limited hardware support, which restricted the widespread implementation of digital tools like Kahoot [31]. Some schools lacked sufficient computers, stable WiFi, or projectors, which reduced students opportunities to engage with digital media during the exploration and analysis phases. His lack of essential hardware and reliable connectivity acts as a systemic barrier in low-resource environments, often forcing teachers to abandon innovative digital lesson plans and revert to traditional, passive teaching methods [50].

Classroom management issues, including student absenteeism, lack of focus, and inconsistent participation, were noted across multiple studies [30], [34]. In classes that used animated videos or PPT-based digital learning, some learners missed key stages of the Discovery Learning process, especially during guided exploration and verification. This condition is further exacerbated by digital distractions, as technology-rich classrooms may encourage off-task behavior and multitasking, which reduce students' attention and engagement and ultimately weaken instructional effectiveness [51]. Some students were also reported to be reluctant to speak or engage in discussions, which reduced collaborative inquiry as an essential component of Discovery Learning [34]. These human factors further limit the successful adoption of digital media even when the tools themselves are pedagogically appropriate.

Overall, the findings across all studies suggest that the successful integration of digital media into Discovery Learning requires more than simply providing digital tools. Stable and accessible technological infrastructure, adequate digital literacy for both teachers and students, sufficient school facilities, and supportive classroom conditions are essential prerequisites. This conclusion is reinforced by a study that developed ADDIE-based interactive multimedia using Genially, which was validated by media, content, and language experts and empirically proven to be valid, practical, and effective in improving elementary students' digital literacy and learning motivation [52]. However, several studies also identify persistent challenges, including limited access to technology in some schools, low teacher competence in developing digital-based learning media, and insufficient adaptation of learning content to students' needs and characteristics, particularly at the junior secondary level, highlighting the need for comprehensive support in terms of infrastructure, continuous teacher training, and learner-centered instructional design [53]. In line with this, classroom-based research on digital media-supported Discovery Learning in elementary schools highlights practical solutions to existing challenges, including upgrading ICT infrastructure, strengthening students' and teachers' digital skills through intensive guidance and training, simplifying instructional approaches, and enhancing student engagement through peer support and accessible digital resources [54]. Without these supporting elements, digital media cannot optimally enhance exploration, experimentation, hypothesis testing, and conceptual reconstruction, key components of the Discovery Learning model.

Conclusion

The overall analysis of the fifteen selected studies demonstrates that digital media plays a significant role in enhancing conceptual understanding within the Discovery Learning model in science education. PhET Simulation emerges as the most effective and frequently used tool, consistently improving student mastery across diverse science topics, while other media such as animated videos, Wordwall, Kahoot, digital modules, and interactive multimedia also contribute meaningfully by strengthening visualization, engagement, and conceptual construction. Digital media is particularly suitable for science materials that require the representation of abstract, dynamic, or complex scientific processes. Topics such as Energy, the

Digestive System, and the Solar System benefit greatly from simulations, animations, and interactive platforms that support exploration, hypothesis testing, and verification within the Discovery Learning stages. These media types help students develop deeper conceptual understanding by enabling active inquiry and independent knowledge formation. Several inhibiting factors, however, still limit the optimal integration of digital media, including unstable internet access, limited digital literacy among teachers and students, unequal school facilities, restrictions caused by paid applications, and classroom-related challenges such as low student focus or absenteeism. Addressing these obstacles is essential for maximizing the effectiveness of digital media in Discovery Learning environments.

Author's Contribution

K. A. Maharani: responsible for developing the research concept, preparing the initial draft, writing the main content of the manuscript, and conducting article identification through database searches using the Publish or Perish application, followed by the initial and advanced screening, as well as analyzing and reviewing selected articles based on the inclusion and exclusion criteria. S. S. A. Q. Barid: responsible for data validation and preparation of the research design. S. R. D. Astuti: responsible for conducting data analysis. S. Wahyuni: the corresponding author and was responsible for preparing the research report and organizing the research findings in a systematic and academic manner as part of the final manuscript.

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