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Differentiated Instruction through Adaptive Learning Platform in Science Education: A Systematic Literature Review

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Abstract: Recent technological advancements have led to various educational innovations, including adaptive Learning, which customizes content and instructional methods to meet the diverse needs and abilities of individual students. Several empirical studies have utilized adaptive learning platforms to support differentiated Learning in science. However, to date, there has yet to be a comprehensive review of the findings in this area. This study aims to explore research trends related to differentiated Instruction through adaptive learning platforms in science education, as documented in Scopus-indexed journal articles published between 2019 and 2024. The research follows PRISMA guidelines, employing the Publish or Perish application for the search system, with data sourced from SCOPUS. The search yielded 368 articles, and screening based on specific inclusion and exclusion criteria resulted in 23 papers that were subsequently analyzed. This study highlights various adaptive technology methods used in science education, emphasizing Learning Management Systems (LMS) and Artificial Intelligence (AI). LMS emerges as the most frequently utilized, followed by AI and assessment platforms. Crucial factors for successful implementation include real-time feedback and accessibility to technology. Although these platforms improve learning outcomes, issues regarding student engagement and satisfaction persist. Educational institutions should assess their technological infrastructure and provide training for educators to leverage new features effectively. Additionally, developers should focus on enhancing personalization options, while further research is necessary to address students' emotional needs better and enhance their motivation.

Keywords: adaptive learning, differentiated instruction, science education, teaching, systematic literature review.

▪ INTRODUCTION

In the 21st-century education era, addressing the increasingly diverse needs of students has become one of the most significant challenges. Especially with the rise of the 4.0 Industrial Revolution, the ability to accommodate individual differences in Learning is becoming even more critical. Education no longer relies on the traditional one-way approach, where the teachers act as the center of Learning and students passively receive information. The shift toward Education 5.0 emphasizes the importance of technology as a tool to support a more student-centered, adaptive, and personalized learning process (Morze and Buinytska 2019). Differentiated Instruction is recognized as a method to address the heterogeneity of students' abilities in the classroom. In line with Education 5.0 trends, technology has emerged as a powerful enabler in addressing the diverse needs of students, particularly in science education. Adaptive learning platforms and educational technologies are increasingly being used to provide personalized learning experiences, where each student can progress at their own pace based on their specific

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learning needs and preferences (Wu and Tsai 2022). These platforms use data analytics to understand individual student's strengths and areas for improvement, thus facilitating differentiated Instruction in real time (Cota-Rivera et al. 2024). Differentiated Instruction, supported by adaptive technologies, allows educators to modify the content, process, and learning environment to match the diverse learning profiles of their students. By using simulations, virtual labs, and interactive multimedia, technology helps create an engaging learning environment that is adaptable to different cognitive levels, effectively implementing differentiated Instruction. This ensures that every student, regardless of their prior knowledge or abilities, can effectively understand complex scientific concepts, fostering inclusivity and reducing the achievement gap in science education (Lahiassi et al. 2024; Santos et al. 2024).

Differentiated Instruction is a learning approach that takes into account differences in students' abilities, interests, and learning styles (Tomlinson 2017). The primary goal of this approach is to ensure that every student receives optimal education tailored to their learning needs. To achieve this, teachers implementing Differentiated Instruction monitor and manage content, processes, products, and the learning environment (Rijal, Aswarliansyah, and Waluyo 2025). This means that teachers can adapt the materials delivered, the teaching methods used, and the expected learning outcomes to meet the individual needs of students. In the context of science education, this approach is particularly relevant as science requires a deep understanding of complex concepts, which cannot always be achieved through uniform teaching methods. Differentiated Instruction provides opportunities for students to access material in ways that are more suited to their learning style preferences, whether through visual, kinesthetic, or auditory modalities and at a level of challenge that aligns with their cognitive abilities (Rizki and Ningsih 2024).

Adaptive Learning Platforms are educational technologies that utilize data analysis and intelligent algorithms to adjust learning materials to the needs and abilities of students in real time (Li et al. 2023; Min et al. 2020; Rincon-Flores et al. 2024). This technology supports Differentiated Instruction very effectively, as it enables personalized learning pathways for each student based on continuous data analysis. These platforms can identify learning patterns, comprehension levels, and student progress and adapt the content provided to better suit each student's profile (Aleksandrovich et al. 2024). In science education, this feature is particularly helpful because many complex concepts require different approaches for different students. This technology allows students who may need more time or a different approach to understand a concept to receive a learning experience tailored to their pace and learning style.

Adaptive Learning often comes with Artificial Intelligence (AI) components that can learn from every student interaction with the platform, thus increasing the precision of providing relevant learning recommendations (Aleksandrovich et al. 2024; Minn 2022). Additionally, approaches such as rule-based systems and data mining are also used in Adaptive Learning. Rule-based systems work by determining rules based on previous data, while data mining analyzes large patterns to draw valuable conclusions for adjusting the learning process (Troussas, Krouska, and Sgouropoulou 2020). By using this technology, teachers can more easily provide a personalized and responsive learning experience for students, ensuring that every student receives an experience suited to their needs and level of understanding.

In science education, the role of Differentiated Instruction supported by Adaptive Learning Platforms is crucial. Science education often involves abstract concepts that require profound explanation and understanding. By using adaptive technology, materials can be delivered in various formats, such as interactive simulations, videos, and virtual labs, which can be adjusted to the level of student understanding. For instance, visual learners may benefit more from animations and diagrams, while other students may need virtual labs to experiment directly. Adaptive Learning Platforms help manage this diversity by providing different content to students based on automatic analysis of their performance and learning style (Jose et al 2024). This ensures that students not only understand scientific concepts but also feel challenged and engaged in the learning process, thereby enhancing their motivation and learning outcomes (Marzuki, Zakaria, and Masruri 2024). Thus, the integration of Differentiated Instruction and Adaptive Learning Platforms can create a more inclusive and practical science learning experience, allowing students with diverse abilities to learn in the way that best suits them (Sahal Fawaiz and Wisodo 2024). This adaptive Learning not only improves students' understanding of scientific concepts but also helps them develop critical thinking and problem-solving skills, which are the main goals of 21st-century science education.

Empirical studies have shown that the use of adaptive learning platforms in science education can significantly improve students' academic outcomes. This approach enhances students' learning outcomes, particularly in terms of understanding concepts and active engagement in the learning process. Students who learn using adaptive learning platforms achieve higher learning outcomes compared to those who learn using traditional methods (Amado and Roleda 2020; Ezzaim et al. 2023; Mudrák, Turcáni, and Reichel 2020). Furthermore, adaptive learning platforms have been found to have a significant impact on students' learning motivation, engagement, and satisfaction with learning experiences (Aleksandrovich et al. 2024; Li et al. 2023; Min et al. 2020). These platforms, therefore, hold great potential for enhancing the effectiveness of science education in the digital era. Despite the numerous studies being conducted, there has not been a comprehensive literature review that identifies trends, key findings, and potential research gaps in the implementation of differentiated Learning through adaptive learning platforms in science education. This gap in the literature underscores the necessity of this research, which aims to provide a comprehensive overview of the developments and directions in related research. By evaluating the extent to which adaptive Learning has contributed to the implementation of differentiated Instruction in the field of science, this study can provide in-depth insights and help determine the necessary steps to optimize the use of this technology within the context of science education.

▪ METHOD

This study's methodology uses a Systematic Literature Review (SLR) technique that goes through several essential steps: (a) identification, (b) screening, (c) eligibility, and (d) inclusion (Page et al. 2021). The journals that span the years 2019 through 2024 and are indexed by Scopus are the source of the data. The keywords used in the literature search include the following terms: Adaptive Learning Platform in Science Education, Personalized Learning in Science Education, Adaptive Learning in Physics Education, Adaptive Learning in Chemistry Education, and Adaptive Learning in Biology Education. We used the Publish or Perish application to gather the data.

Predefined inclusion and exclusion criteria were utilized to direct the article selection process. The target population included middle school, high school, and college students. These criteria were practically implemented by selecting studies that clearly identified participants at these educational levels to ensure relevance to the targeted group. Publications such as empirical research, literature reviews, conceptual studies, journal articles, conference proceedings, and peer-reviewed articles were also included. These were applied by examining the publication type and verifying peer-review status to maintain the quality and credibility of the selected works. The study is centered on science education, focusing on physics, chemistry, and biology. This was put into practice by selecting studies that focused explicitly on adaptive Learning within these science subjects, ensuring alignment with the goal of enhancing scientific literacy. Conversely, research involving kindergarten and elementary school students, articles that are reports or book chapters, studies without technology usage, and those not related to science education were excluded.

Table 1. Inclusion and exclusion criteria

Inclusion	Exclusion
Population: - Middle School - High School - University	**Population:** - Elementary School - Kindergarten
Article Characteristics: - Empirical Study - Literature Review - Conceptual Study - Journal - Proceedings	**Article Characteristics:** - Book Chapter - Report
Focus Area: - Science Education - Physics - Chemistry - Biology	**Focus Area:** - Non-Science

The systematic process followed PRISMA guidelines proposed by the Ottawa Methods Center for reporting items for systematic reviews and meta-analyses (Rethlefsen et al. 2021). Figure 1 shows the process flow employed in this study for identification, screening, eligibility, and inclusion steps of the process.

To provide an in-depth overview of Differentiated Instruction through Adaptive Learning Platforms in Science Education from the 23 identified papers, four research questions were proposed: the adaptive technology approaches applied in science education platforms, the factors influencing the successful implementation of adaptive learning platforms in science education, features that can support differentiated Learning using adaptive learning platforms in science education, and the impact of adaptive learning platforms on science education. First, all papers were thoroughly reviewed by three reviewers, and summaries were created for each study to address the four research

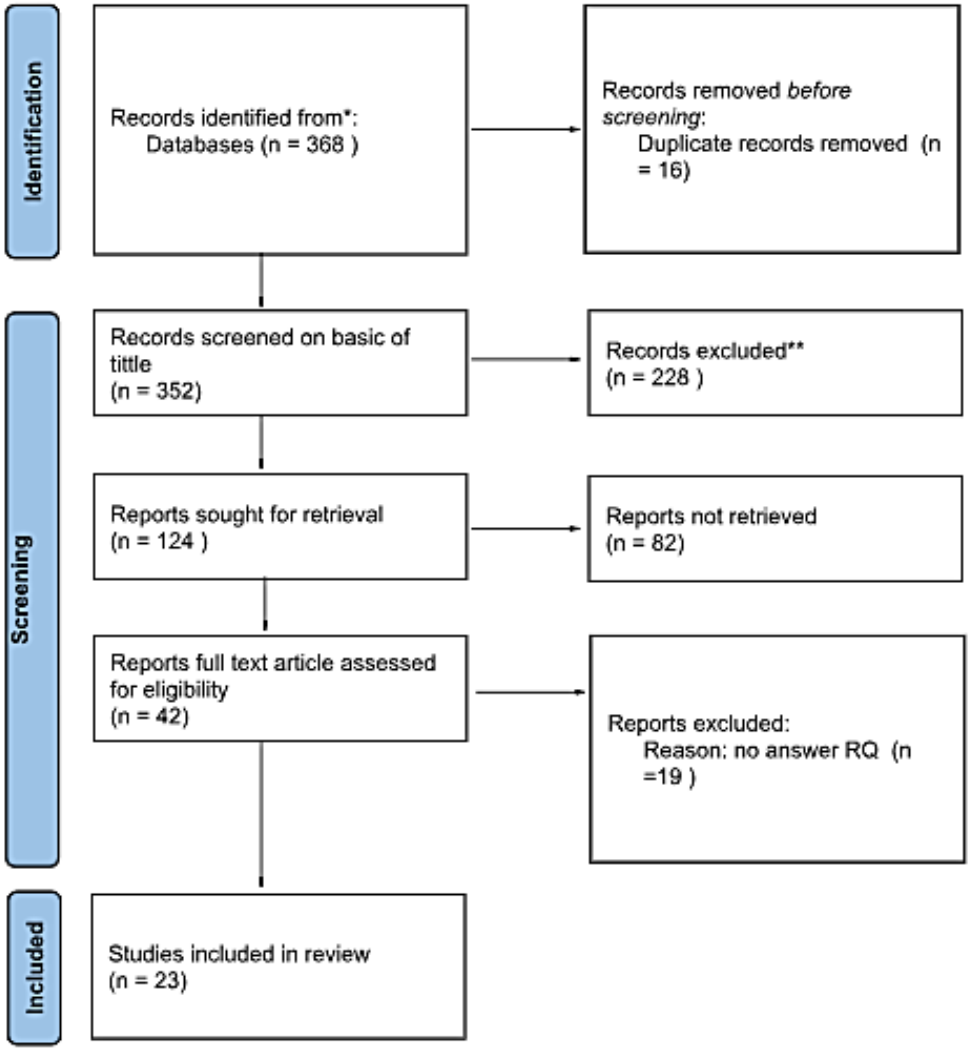


Figure 1. PRISMA process flow chart of the adaptive learning systematic review

questions. These summaries were then categorized and analyzed to respond to the research questions. The findings were organized in a spreadsheet table, which was then analyzed using percentages of each categorization applied to answer the research questions. The categorized answers for each research question are presented in the table 2.

Table 2. Categories of research questions answer

Research Question	Categorized
Adaptive technology approaches applied in science education platforms	Artificial Intellegent (AI); Augmented Reality (AR); Learning Management System (LMS); Assessment; Simulation; Gamification
The factors influencing the successful implementation of	Technology Accessibility; User Readiness; User Interaction; Learning Sytle; Emotions; Preferences; Demographics; Real-time feedback; Learning

adaptive learning platforms in science education	Costumization; Content Quality; Student Initial Abilities; Institutional Policy and Support
Features that can support differentiated learning using adaptive learning platforms in science education.	Learning Style Personalization; Interactive Media; Assessment Personalization; Real-time Feedback; Content Personalization; Time Flexibility
The impact of adaptive learning platforms on science education	Efficiency/ Effectiveness; Satisfaction; Skills; Collaboration; Problem Solving; Motivation; Student Engagement; Interest; Learning Outcomes; Argumentation Ability

▪ RESULT AND DISSCUSSION

This section presents the findings of the systematic literature review, organized into two main parts. The first part, Article Data Description, provides an overview of the characteristics of the included studies, including publication types, geographical distribution, research methods employed, educational levels, and focus areas within science subjects. These descriptive data offer insights into the broader research landscape on adaptive learning platforms in science education.

Article Data Description

Table 1 provides a comprehensive overview of the critical characteristics of the 23 studies included in this systematic review. The data summarized in the table include publication types, geographical distribution of the studies, research methods used, educational levels targeted, and the specific focus areas within science subjects. This descriptive information offers a foundational understanding of the research landscape on adaptive learning platforms in science education.

Table 3. Article data description

No	Data		Percentage
1	Type of publication	Journal	82.60%
		Conference Paper	17.40%
2	Country Distribution	United States of America	23.8%
		Indonesia	19.0%
		China	14.3%
		Mexico	4.8%
		Morocco	4.8%
		Columbia	4.8%
		European Country	4.8%
		Australia	4.8%
		German	4.8%

No	Data		Percentage
		Sweden	4.8%
		Dutch	4.8%
		Philippines	4.8%
3	Educational Level	Higher Education	69.6%
		High School	30.4%
4	Field of Focus	Physics	36.0%
		Science	28.0%
		Chemistry	24.0%
		Biology	12.0%
5	Research Methods	R&D	25.0%
		Experimental Study	16.7%
		Mix Method	16.7%
		Review	12.5%
		Survey	12.5%
		Quantitative	8.3%
		ADDIE	4.2%
		Observation	4.2%

The data above shows that research on adaptive Learning is more widely published in Scopus-indexed international journals compared to proceedings. The country that conducts the most research on this topic is the United States of America, and this learning approach is predominantly used in Higher Education. This is because students in higher education have diverse backgrounds, and adaptive Learning allows each student to learn at their own pace and understanding, enhancing the effectiveness of Learning. Additionally, this system provides real-time feedback and content adjustments so students who need more time or support can be assisted. At the same time, those who have already mastered the material can move on to the next topic (Troussas et al. 2020).

Adaptive Learning also supports the flexibility that is crucial in higher education, where many students need to balance their studies with other responsibilities. With personalized and flexible access, these platforms enable more independent and student-centered Learning, significantly improving learning outcomes (Cardenas et al. 2022)The study results also indicate that physics is the field that conducts the most research on this topic, as physics involves complex concepts that require deep understanding. Adaptive learning helps facilitate this understanding by providing materials suited to each student's level of comprehension, thereby enhancing learning effectiveness (Levin and Isakova 2024). Currently, adaptive learning platforms are rapidly evolving and are supported by extensive R&D research in this field compared to other research designs. This indicates significant potential for further development of similar platforms and others to continue being adapted to meet differentiated learning needs.

Key findings from the included studies are presented in the following diagrams to answer the research questions guiding this review. Each diagram illustrates the

distribution of factors related to the respective research question, providing a visual summary of the results.

Adaptive Technology Approaches Applied in Science Education Platforms

The review identified several adaptive technology approaches used in the included studies. The most commonly applied technology was Learning Management Systems (LMS), which accounted for 37% of the studies. This was followed by Artificial Intelligence (AI) and Assessment Platforms, both representing 18.5% of the total. Augmented Reality (AR) was utilized in 14.8% of the studies, while Gamification appeared in 7.4% of the studies. Simulations, though less frequently used, were present in 3.7% of the research, as can be seen in Figure 2.

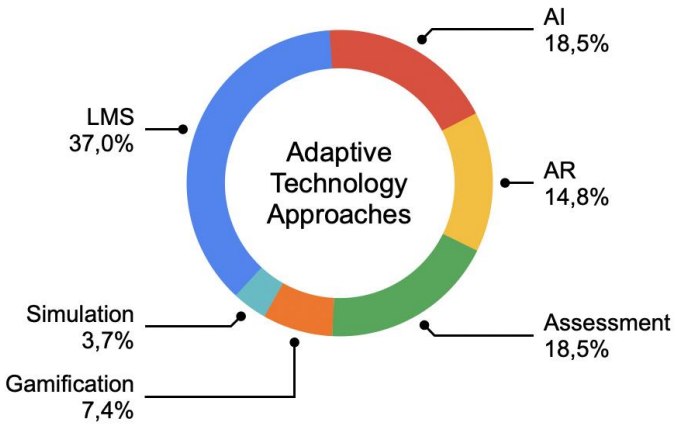


Figure 2. Adaptive technology approaches

Abbreviations:
LMS : Learning Management System
AR : Augmented Reality
AI : Artificial Intelligence

The analysis of the studies revealed that LMS-based platforms were the most commonly implemented adaptive technology in science education. AI-powered tools and real-time assessments were also frequently utilized, while approaches like Gamification and simulations appeared less frequently. The prevalence of LMS-based platforms reflects their widespread use in modern educational environments due to their flexibility, scalability, and ability to integrate various learning features such as content management, assessment, and communication between students and teachers. LMS also supports personalized learning pathways by providing easy and organized access to learning materials, enabling teachers to deliver content tailored to individual student needs and efficiently monitor their progress. In the context of science education, LMS facilitates differentiated instruction by allowing teachers to adapt learning content, tasks, and assessments to match the diverse needs and learning profiles of students, thereby fostering a more inclusive and effective learning environment (Aleksandrovich et al. 2024; Katz et al. 2021). The increasing use of AI-based technologies also indicates a shift towards more personalized learning experiences, where student progress can be tracked, and learning

content can be adjusted in real-time (Katz et al. 2021). This aligns with (Martin et al. 2020), where AI is being leveraged to enhance student outcomes through automation and data-driven insights.

These findings are consistent with other studies on adaptive Learning, which highlight the role of AI in improving learning outcomes through personalization. However, the limited use of Gamification and simulations in this review suggests that these approaches, while promising in theory, may still face practical challenges in implementation, such as high costs or a lack of teacher training (Al-Rayes et al. 2022). This is due to the integration of adaptive elements in game-based Learning (GBL), which requires more complex development. Adaptive learning systems need to adjust difficulty levels, teaching methods, and materials based on individual performance and learning styles (Aeiad and Meziane 2019). This requires deep data analysis and complex personalization algorithms (Rezapour, Fatemi, and Nematbakhsh 2024), which are not easily applied in a game context.

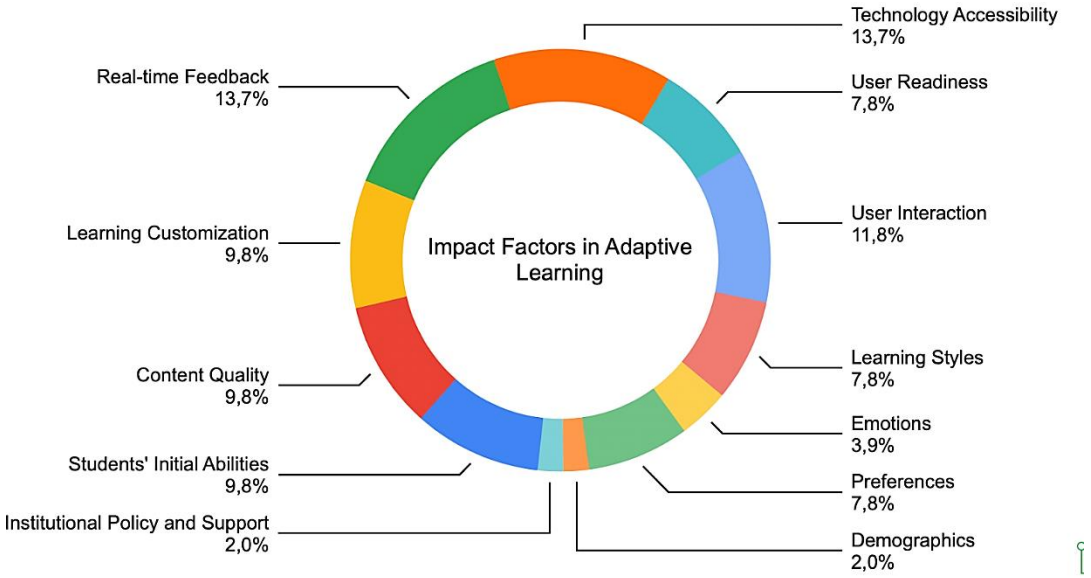
Additionally, adaptive simulations must be able to adjust scenarios or difficulty levels according to the cognitive abilities of individual students, adding another layer of complexity to their development (Kinner and Whitaker 2022). As a result, factors such as high development costs, lack of technological resources, and the need for teacher training to utilize these technologies become significant barriers to the implementation of adaptive Gamification and simulations in differentiated Learning.

The Factors Influencing the Successful Implementation of Adaptive Learning Platforms in Science Education

The studies identified various factors that influence the success of adaptive learning platforms in science education. As shown in Figure 2, the most prominent factors were Real-time Feedback and Technology Accessibility, each cited in 13.7% of the studies. User Interaction was highlighted in 11.8% of the research, while Students' Initial Abilities, Content Quality, and Learning Customization were each reported in 9.8% of the studies. Other notable factors included User Readiness, Learning Styles, and Preferences, each accounting for 7.8% of the findings. Less frequently mentioned factors were Emotions (3.9%), Demographics (2.0%), and Institutional Policy and Support (2.0%), as can be seen in Figure 3. These results highlight the multifaceted nature of adaptive learning implementation, with a particular emphasis on technology-related factors and the ability to provide personalized feedback to students.

The findings indicate that the most influential factors for the successful implementation of adaptive learning platforms in science education are real-time feedback, technology accessibility, and user interaction. Additionally, factors such as students' initial abilities, content quality, and learning customization also played a significant role, while less frequently mentioned factors included emotions, demographics, and institutional policy and support. The prominence of real-time feedback and technology accessibility highlights the critical role that technology infrastructure and timely instructional adjustments play in student success. In science education, where students often grapple with complex, abstract concepts, immediate feedback can help to correct misunderstandings quickly and keep students on track

Figure 3. Impact factors in adaptive learning



(Martin et al. 2020; Müller et al. 2022). This is in line with the principle of differentiation, where teachers must continuously monitor and assess students' progress to provide support tailored to each individual's needs (Cardenas et al. 2022; Cinque et al. 2024). Similarly, access to technology is foundational—without reliable platforms, the potential benefits of adaptive Learning cannot be fully realized. The importance of user interaction also points to the need for engaging, dynamic learning environments that can adapt to the diverse needs of students.

These results are in line with previous studies on adaptive Learning that emphasize the value of real-time feedback in improving learning outcomes (Koć-Januchta et al. 2022; Vyas, Kemp, and Reid 2021). Furthermore, the emphasis on technology accessibility mirrors broader findings on digital divides in education, particularly in resource-constrained environments. Interestingly, while the literature often underscores the role of emotions and institutional support in successful implementation (Ezzaim et al. 2023; Vincent-Ruz and Boase 2022), these factors were not heavily featured in the studies reviewed, suggesting that these elements may be under-explored in current research. In science education, the need for personalized Instruction is exceptionally high due to the variability in students' prior knowledge and the conceptual difficulty of subjects like physics and biology. Real-time feedback allows teachers to provide targeted interventions, helping students overcome misconceptions early (Troussas et al. 2020).

Meanwhile, technology accessibility ensures that all students, regardless of their socioeconomic background, can benefit from the adaptive learning platform's personalized features (Vyas et al. 2021). Interestingly, factors such as demographics and institutional policy were rarely mentioned, which may suggest that these aspects have been underexplored in the context of adaptive learning platforms. Alternatively, the studies included in this review may have prioritized technology-related factors over socio-institutional factors. Future research could investigate how institutional support and demographic factors such as socioeconomic background or cultural differences impact the success of adaptive learning platforms.

Further research is needed to examine how adaptive learning platforms can better cater to emotional engagement and student motivation in science education. Additionally,

more attention should be given to understanding the role of institutional support and policy in enabling the effective integration of these technologies in different educational contexts. Studies that focus on the impact of user readiness and interaction design may also help to identify strategies for maximizing the effectiveness of adaptive learning systems.

Features That can Support Differentiated Learning Using Adaptive Learning Platforms in Science Education

The analysis identified several personalization features integrated into adaptive learning platforms. The most commonly applied feature was Content Personalization, which was present in 30% of the studies. Real-time Feedback was the second most prevalent feature, implemented in 26% of the cases. Other notable personalization features included Assessment Personalization, cited in 18% of the studies, and Interactive Media, used in 12% of the platforms. Time Flexibility appeared in 10% of the studies, while Learning Style Personalization was less common and featured in only 4% of the research, as can be seen in Figure 4. These findings illustrate the range of personalization approaches applied within adaptive learning platforms, with a strong emphasis on content customization and real-time feedback mechanisms.

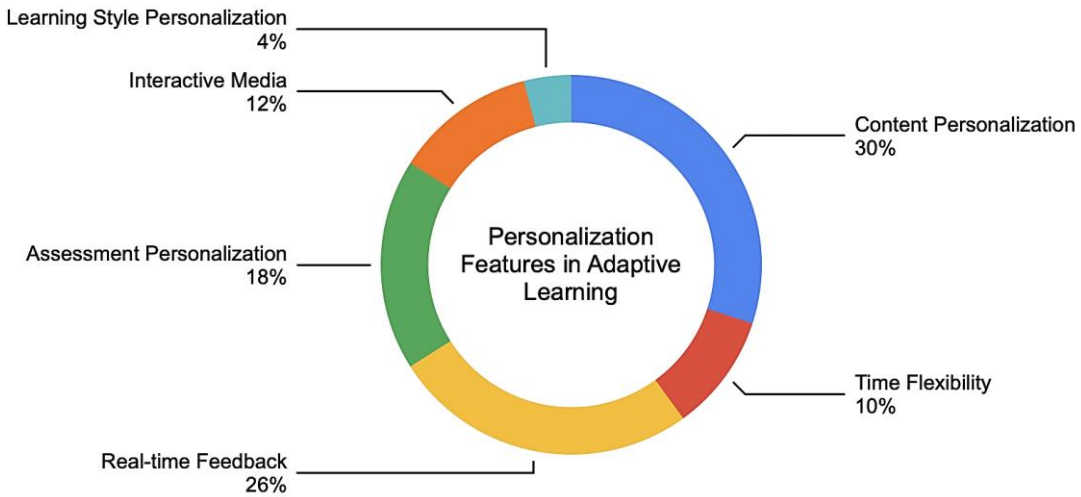


Figure 4. Personalization features in adaptive learning

This analysis shows that the most common features of adaptive learning platforms that support personalized Learning in science education are content personalization and real-time feedback. Additionally, personalized assessment and time flexibility are also frequently found, while interactive media and learning style personalization appear less often in the reviewed studies. In differentiated Learning, teachers need to tailor materials and teaching methods to the needs, understanding levels, and learning styles of each student. Content personalization allows the adjustment of learning materials to match the individual student's knowledge level, which is highly valuable in science education, where understanding can vary significantly among learners (González et al. 2019; Hwang and Fu 2020). The real-time feedback feature also supports the principle of differentiated Learning by providing quick responses to students' efforts and learning outcomes. This

aligns with the need to offer immediate and relevant support so that students can correct mistakes or adjust their learning strategies (Istiyono et al. 2020). These two features—content personalization and real-time feedback—enable adaptive platforms to tailor learning to individual student needs, which is at the core of differentiated Learning. This creates a dynamic and responsive environment where each student receives appropriate support according to their ability and continuously progresses (Vincent-Ruz and Boase 2022).

Moderate inclusion of features like personalized assessment and time flexibility also aligns with differentiated learning principles, where teachers adjust methods and evaluations to meet individual student needs. Personalized assessment is at the heart of differentiation, as it allows teachers to measure student's progress based on their unique experiences and abilities (Istiyono et al. 2020; Rıos et al. 2020). In this way, assessment is no longer uniform but instead tailored to reflect each student's understanding and development, as required in differentiated Learning. Time flexibility also supports differentiated Learning by giving students the freedom to study at times that suit them best. This provides students with greater autonomy in managing their study time, allowing them to delve into more complex material, such as science, at a pace that matches their needs (Cardenas et al. 2022; Rincon-Flores et al. 2024). This flexibility supports a student-centered approach, where the learning process is adapted to respect the rhythms and learning styles of each individual, in line with differentiated learning principles focused on individual differences.

Interactive media, although less frequently implemented, adds an engaging dimension to the learning process, allowing students to interact with scientific concepts more dynamically. However, the low frequency of learning style personalization may indicate an area where adaptive platforms can still be improved, as students often have different learning preferences that current systems have not fully accommodated. Given the importance of differentiated Instruction in modern pedagogy, the low integration of learning style personalization suggests that adaptive platforms still have room to grow in supporting diverse learning needs (Li et al. 2023). Compared to existing literature, these findings highlight the strengths and weaknesses of how adaptive learning platforms are utilized for instructional differentiation in science education. While content personalization and feedback mechanisms are well established, features that support deeper forms of differentiation—such as adaptation to specific learning styles or the integration of interactive media—remain less common. This indicates opportunities for further development of adaptive systems to enhance their ability to provide personalized and student-centered learning experiences.

The Impact of Adaptive Learning Platforms on Science Education

The analysis shows that the most prominent impacts of adaptive learning platforms in science education are on learning outcomes and efficiency/effectiveness, each representing 25 % of the reviewed studies. These results indicate that adaptive platforms significantly contribute to improving students' academic performance and the efficiency with which they learn complex scientific concepts.

Student engagement was noted in 15.7% of the studies, showing that adaptive platforms play a crucial role in maintaining students' active participation during lessons. However, interest (6%) and satisfaction (8%) were mentioned less frequently, suggesting

that while students engage with the material, further efforts might be needed to increase their overall enjoyment and satisfaction with the learning process.

Other areas, such as skills development (4%), problem-solving (4%), and motivation (4%), were reported less frequently, indicating that while adaptive platforms have the potential to foster these aspects, they are currently underexplored or not fully integrated into existing systems. Similarly, collaboration (6%) and argumentation ability (2.0%) were mentioned in only a few studies, pointing to the need for adaptive platforms to more fully support collaborative Learning and critical thinking skills in science education. The result can be seen in Figure 5.

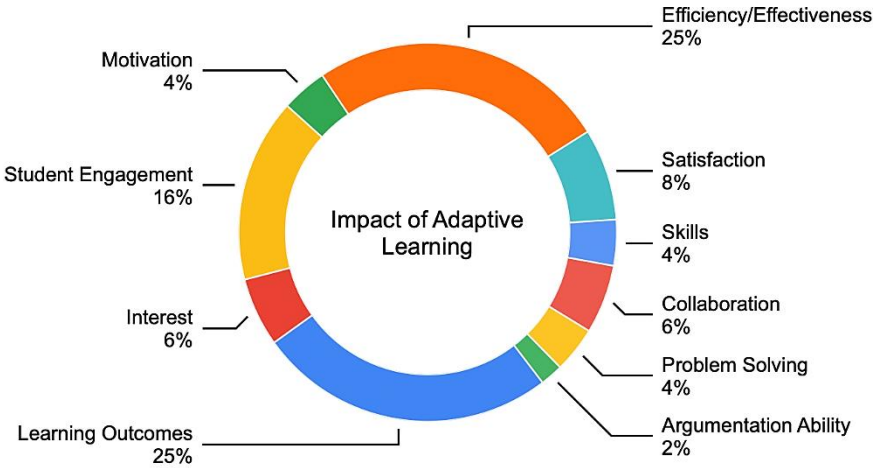


Figure 5. Impact of adaptive learning on science education

The findings from this study indicate that adaptive learning platforms have a significant impact on learning outcomes and efficiency/effectiveness, both of which are the most frequently reported improvements in the reviewed studies. Emphasis on these two areas shows that adaptive platforms, through their ability to provide personalized content and real-time feedback, are highly effective in enhancing students' understanding and mastery of scientific concepts. This aligns with the existing literature, which often highlights adaptive learning systems as essential tools for optimizing academic performance by tailoring Instruction to individual learning needs (Nor and Halim 2021). The intense focus on efficiency and effectiveness reflects the platform's ability to streamline the learning process, allowing students to progress through the material with incredible speed and ease (Ramadhani et al. 2024; Soraya 2022). This is particularly important in science education, where students often face complex topics that benefit from adaptive pacing and targeted feedback. By personalizing the learning journey, adaptive platforms help reduce cognitive overload and improve instructional delivery effectiveness (Minn 2022). Additionally, this is highly relevant to differentiated Learning, where adaptive platforms can adjust content according to each student's cognitive level and needs, ensuring they learn at the pace and method that suits them best.

Student engagement, mentioned in 16% of the studies, highlights the role of adaptive platforms in keeping students actively involved in their studies. However, engagement alone does not guarantee student satisfaction, as evidenced by the lower frequency of interest improvement (6%) and satisfaction (8%). This suggests that while

adaptive platforms succeed in engaging students in the learning process, they may need to incorporate more engaging and enjoyable elements, such as Gamification or interactive media, to boost student motivation and enjoyment further (Zourmpakis, Kalogiannakis, and Papadakis 2023). In the context of differentiated Learning, it is important to leverage these elements to capture the attention of students with varying interests and learning preferences (Min et al. 2020). The low frequency of impact on skill development (4%), problem-solving (4%), and collaboration (6%) highlights areas where adaptive platforms may still fall short. Science education often requires students to develop practical skills and engage in collaborative problem-solving, both of which are critical for success in STEM fields. Although adaptive learning systems are highly effective at delivering personalized content, current platforms may not fully support the development of these higher-level skills. Therefore, the development of more collaborative features and complex problem-solving activities is also a key component of differentiated Learning to meet the diverse needs of students.

The minimal mention of argumentation skills (2.0%) further underscores the need for adaptive platforms to evolve beyond mere content delivery and focus on the development of critical thinking and scientific argumentation skills. Science education, by its nature, requires students to engage in reasoning, debate, and justification of their findings, which are crucial components of scientific literacy. In the context of differentiated Learning, fostering these skills through activities tailored to individual ability levels becomes increasingly important. Platforms that integrate activities encouraging argumentation and critical discussion are likely to provide a more holistic approach to science education while supporting differentiated Learning to address diverse academic needs (Heeg and Avraamidou 2023).

▪ CONCLUSION

This research reveals various adaptive technology approaches applied in science education platforms, with a focus on Learning Management Systems (LMS) and Artificial Intelligence (AI)-based technologies. The results of the systematic literature review indicate that LMS is the most commonly used adaptive technology, accounting for 37%, followed by AI and assessment platforms. The analysis also identified factors that influence the successful implementation of adaptive learning platforms, with real-time feedback and technology accessibility being the most influential factors, accounting for 13,7%. Additionally, personalization features such as content personalization (30%) and real-time feedback (26%) are crucial in supporting differentiated Learning in science education. In addition, differentiated learning through adaptive learning platforms is effective and efficient for use in the learning process, and effectively improves learning outcomes in science education, as indicated by studies examining this at 25% each.

From an impact perspective, adaptive learning platforms have been shown to improve learning outcomes and efficiency in the student learning process. However, challenges remain in terms of student engagement, interest, and satisfaction with their learning experience. These findings suggest that while these platforms succeed in increasing student engagement, they need to integrate more elements that enhance student satisfaction and motivation, such as Gamification and interactive media.

Based on this review, schools and educational institutions need to evaluate their technological infrastructure to ensure adequate accessibility for all students. Investment

in hardware and software that supports LMS and AI platforms should be a priority. Educators need to receive sufficient training on the use of adaptive technology. These training programs should cover ways to leverage new features within platforms to enhance student learning experiences. Furthermore, adaptive learning platform developers should focus on developing deeper personalization features, including personalized learning styles and interactive media. This can help meet the diverse learning needs of students.

Further research is needed to explore how adaptive learning platforms can better address students' emotional needs and enhance their motivation. More interactive and gamified approaches should be considered. Additionally, there is a need to explore the impact of factors such as institutional support, demographics, and educational policies on the successful implementation of adaptive learning platforms.

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