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PERSONALIZED LEARNING EXPERIENCES EXPLORING ADAPTIVE E-LEARNING SYSTEMS FOR DIFFERENT LEARNING STYLES

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ABSTRACT

Objective: This research aims to provide an overview of the development of adaptive e-learning systems designed based on individual learning style preferences. The main focus is to identify adaptive models, supporting technologies, and challenges associated with the implementation of personalization in learning.

Research Design & Methods: This research uses the literature review method by analyzing various scientific articles, research reports, and recent publications related to adaptive e-learning.

Findings: This research found that learning style preference-based adaptive e-learning systems have significant potential to improve learning effectiveness by presenting relevant and personalized content. However, its success requires solutions to challenges such as accuracy of preference data collection, privacy protection, and development of flexible and reliable technologies.

Implications & Recommendations: E-learning developers are advised to leverage AI for advanced personalization, ensure inclusive design, and implement data protection policies. Further empirical research is needed to test the effectiveness of adaptive models in various learning contexts.

Contribution & Value Added: This research contributes to enriching theoretical and practical insights regarding the development of learning style-based adaptive e-learning systems. This review not only offers guidance for educational technology developers but also opens up further research opportunities to address challenges and improve the quality of online learning globally.

Keywords: adaptive e-learning, learning styles, learning technology

JEL codes: I20, I21, O32
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INTRODUCTION

The rapid development of internet technology, various digital applications such as e-commerce, e-banking, e-government, and others have now become an inseparable part of everyday life including e-learning. E-learning, as one of the implementations of information technology in education, has offered easy access to learning without time and space limitations. In the form of virtual school, e-learning allows learners to follow the learning process online, access materials, interact with teachers and fellow learners, and do assignments and exams online. Online learning (e-learning) requires new mechanisms to recognize and accommodate different learning styles.

Adaptive e-learning systems have become a new trend in online education, aiming to provide a more flexible and personalized learning experience than the "one-size-fits-all" approach (Faisal et al., 2015). These systems are designed to customize learning materials, the way they are presented and the interactions provided, based on the learning style preferences, unique needs and

knowledge level of individual users. By utilizing advanced technologies such as artificial intelligence and machine learning algorithms, the system is able to provide relevant recommendations, design customized learning paths, and facilitate the achievement of more optimal learning outcomes (Rishard et al., 2022). This approach not only increases learner engagement and motivation, but also provides greater flexibility to learn anytime and anywhere, making it an essential solution in the increasingly complex and diverse digital education era.

Learning style-based adaptive e-learning is one of the innovative approaches in education that aims to improve the effectiveness of learning by customizing materials and delivery methods according to the individual characteristics of learners. Different learning styles, such as visual, auditory, kinesthetic, or other preferences, affect the way students understand and absorb information (Sayed et al., 2020). Traditional e-learning systems tend to use a uniform approach that is unable to meet the unique needs of each student. Therefore, adaptive approaches are relevant as they can improve student engagement, motivation and learning outcomes.

Some researches show the importance of adaptation in e-learning systems, especially by considering learning styles, knowledge levels, and interests of learners (Jovanovic & Jovanovic, 2015; Talaghzi et al., 2020). According to Rishard et al., (2022) research, personalizing learning paths based on students' learning styles and knowledge levels not only improves academic performance but also their satisfaction with the learning process. For example, the "Adaptivo" system is able to customize learning paths based on students' preferences and needs, which is proven to significantly improve learning outcomes. Similarly, the "Cybele" system that uses the Myers-Briggs Type Indicator (MBTI) personality model to customize learning styles showed improved performance over traditional learning methods (Samonte et al., 2023).

The development of adaptive e-learning systems presents significant challenges, especially in terms of the accuracy of student learning style identification and the effectiveness of adaptive interventions. Adaptive systems often rely on algorithms that require accurate and representative data to identify learning styles such as visual, auditory or kinesthetic. However, this process can be complicated as students often exhibit inconsistent combinations of learning styles, making it difficult for the system to provide appropriate recommendations (Talib et al., 2022). In addition, the effectiveness of adaptive interventions depends on the system's ability to design relevant and flexible learning content. Many platforms are not yet able to adapt to individual needs in real-time, so students do not always get the optimal learning experience (Manalu, 2022). This challenge is exacerbated by the limited technological infrastructure in some areas, which hinders the ability to fully access adaptive features (Widyaningsih et al., 2020).

To overcome these obstacles, further research and development is needed to improve the accuracy of the algorithms, ensure the compatibility of the system with various learning styles, and optimize the infrastructure to support wider and more effective use. The adoption of artificial intelligence (AI) technology in adaptive systems has opened up new opportunities to improve adaptation accuracy by using machine learning algorithms to dynamically detect student learning style patterns. With this approach, the system can provide a more personalized learning experience that suits individual needs (Essa et al., 2023). Therefore, it is important to conduct a comprehensive review of technological developments, implementation challenges, and potential solutions to ensure adaptive e-learning systems can make a significant impact in education.

In the development of these systems, machine learning algorithm-based approaches, such as reinforcement learning and knowledge graph-based models, have proven to be effective in personalizing learning paths as well as providing relevant material recommendations according to users' needs and ability levels (Aziz et al., 2021; Chen & Huang, 2023). These systems not only improve learning outcomes, but also ensure long-term information retention with methods that suit individual learning styles. The success of this system lies in its ability to not only deliver relevant material but also improve long-term retention of information. Visual learning styles, for example, benefit greatly from interactive diagrams, while kinesthetic styles are more interested in practical activities that involve direct manipulation of objects or digital simulations. Research by Ristić et al., (2023) shows that this kind of learning style-based personalization can increase student motivation and retention by up to 30% compared to traditional learning methods.

Adaptive learning systems aim to create personalized and effective learning experiences by adjusting the level of difficulty of the material and the method of delivery based on learners' abilities and learning styles. This approach is based on the idea that each individual has a unique level of understanding and learning preferences, so uniform learning is often not optimal. In this system, learning materials are dynamically organized according to learners' abilities, which can be identified through pre-tests, data-based evaluations, or the results of interactions with the system. For example, students with basic understanding are given simpler materials to build their foundation, while higher ability students are directed to more complex and in-depth tasks. This customization helps reduce boredom in more advanced students and prevents frustration in those who struggle to understand the material. So, This paper will analyze the importance of learning style-based adaptation in e-learning systems, as well as evaluate the challenges and potential solutions to improve the effectiveness of digital learning.

LITERATURE REVIEW

E-Learning

E-learning is a technology-based learning system that allows the education process to take place anytime and anywhere. The definition of e-learning includes the use of information and communication technology (ICT) to deliver learning materials online. It includes various formats such as online courses, distance learning and hybrid learning, all of which are designed to support interaction between teachers and learners. These systems are rapidly evolving in response to the needs of modern education, especially in supporting flexibility of learning time and place, as well as enabling wider access to educational resources (Valverde-Berrocoso et al., 2020).

Basically E-learning aimed at providing applications to share information, knowledge, and assist learners in learning activities efficiently and effectively by involving technology (Bejjar & Boujelbene, 2016). E-learning has become increasingly prevalent in higher education over the past two decades, forcing changes in traditional academic roles (Islam et al., 2015). The main advantage of e-learning is its ability to provide inclusive and innovative access to education through an online platform. It enables the use of learning management tools (LMS), interactive teaching materials, and technology-based evaluation to improve student understanding and learning performance. In addition, e-learning has been shown to improve key competencies such as critical thinking, communication and digital literacy skills, which are increasingly relevant in the digital era (Al-Fraihat et al., 2020; Marín Suelves et al., 2021).

E-learning has become increasingly popular in recent years, particularly in response to the COVID-19 pandemic.E-learning encompasses various forms of electronic technologies and the use of information and communication technologies (ICT) with mobile technologies in academic settings, including online education and distance learning (Culduz, 2024; Allen & Taylor, 2017). In academic settings, E-learning often involves the use of online learning applications and Web 2.0 technologies to create new models for education and training to support collaboration, information exchange and user interaction (Bejjar & Boujelbene, 2016). For example, features such as discussion forums, chat and comments adopted from Web 2.0 technologies have been shown to enhance learning interactivity as well as student motivation through increased system credibility and positive social influence (Mupti et al., 2020).

E-learning has been a significant innovation in education, utilizing technology to improve accessibility, effectiveness and collaboration in the learning process. There are several key aspects of e-learning highlighted in the literature including:

1. Use of digital platforms and repositories for research sharing and scientific communication (Owan et al., 2022).
2. Adoption of electronic journals and electronic information sources by academics (Arshad & Ameen, 2014).
3. Adoption of electronic portfolios to support self-regulated and co-regulated learning (Lam, 2022).
4. Integration of research materials into e-learning courses to promote knowledge building

between educators and learners (Chua & Bernardo II, 2011).

The literature also suggests that e-learning has brought about major changes in education, but presents significant challenges such as increased workloads for academics, limited internet access and unprepared infrastructure. Technical constraints and lack of training in online pedagogy hinder the optimization of online learning, especially in regions with less developed digital infrastructure. However, blended learning models offer a solution by combining the advantages of online and face-to-face learning, creating a more effective and flexible learning experience (Islam et al., 2015; Mgoduka & Zwane, 2023).

However, blended learning models offer a solution by combining the advantages of online and face-to-face learning, creating a more effective and flexible learning experience. This model not only offers flexibility in the timing and place of learning but also retains the element of live interaction that is essential for student engagement. With a holistic approach and adequate support, e-learning continues to grow as an integral part of the education system, especially in higher education institutions, which are increasingly adopting blended learning as the primary mode of teaching in the future (Mgoduka & Zwane, 2023).

Adaptives E-Learning Platform

Adaptive e-learning platforms have emerged as a significant advancement in educational technology in recent years due to their ability to personalize learning experiences that offer personalized learning experiences tailored to the needs, abilities, and preferences of individual learners. These platforms utilize various technologies and methodologies to tailor educational content to each learner's needs, preferences, and abilities by using various criteria, parameters, and adaptation algorithms in creating a customized learning environment (Gligorea et al., 2023; Talaghzi et al., 2020). The integration of artificial intelligence (AI) and machine learning (ML) algorithms has been instrumental in optimizing learning pathways, increasing engagement, and improving academic performance (Gligorea et al., 2023).

The core concept of adaptive e-learning is to match the needs and goals of students and teachers as closely as possible, adapting course content and progression accordingly (Tsolis et al., 2010). These systems use artificial intelligence (AI) and machine learning techniques to recommend appropriate content and preferred learning models to users (Yu, 2024). The adaptation process considers factors such as learning style, visual, auditory, reading/writing, and kinesthetic (VARK) preferences, and Bloom's taxonomy (Sayed et al., 2020).

Adaptive e-learning platforms are designed to personalize the learning experience by tailoring educational content and processes to learners' individual needs. The system leverages data-driven insights and artificial intelligence to assess learners' abilities, preferences, and learning styles, offering a customized approach to education. For example, the integration of knowledge graphs and learner portraits enables platforms to match educational content to individual competencies and goals, thereby increasing effectiveness, particularly in open education for learners (Chen & Huang, 2023). Similarly, adaptive platforms leverage AI-based models, such as reinforcement learning, to design personalized learning trajectories based on cognitive and behavioral profiles.

The current emphasis on adaptive mechanisms, such as real-time feedback and dynamic content generation, allows these systems to support a variety of learning objectives while addressing specific challenges, such as limited instructor availability or diverse learner backgrounds (Talaghzi et al., 2020). Adaptive platforms are also important in promoting inclusivity, allowing learners with varying abilities and learning speeds to achieve their goals more effectively (Muralidharan & Parthiban, 2020).

By combining features such as multimodal content (text, audio, visual), these platforms not only cater to individual preferences but also increase engagement and retention. In addition, the use of advanced analytics and gamification models has been shown to increase motivation and provide a more interactive learning environment, supporting both educators and learners in achieving better outcomes (Maher et al., 2020). Adaptive e-learning platforms represent a

transformative change in education, enabling personalized, efficient and scalable solutions for diverse learners in a digitally-driven world.

Learning Style Models

Learning style models are defined by experts as an approach that explains how individuals optimally process information based on their unique preferences and characteristics. Valencia Usme et al., (2023) suggested that learning styles include dimensions such as active-reflective, sensory-intuitive, visual-verbal, and order-global, which aim to tailor learning methods to students' needs. According to Rashid et al., (2023) learning style is an individual's preference for a particular method of understanding material, which is important in customizing online learning activities to meet students' needs. Meanwhile, Lin et al., (2022) describe learning style as the internal cause of each individual's unique learning behavior, allowing adaptation of learning content to increase student motivation. Thus, learning style models not only serve to understand variations in learning, but also become an important tool to personalize learning to make it more effective and relevant.

In the context of technology-based learning, learning styles have been used to create adaptive learning systems, as applied in virtual reality and blended learning courses. Where learning styles are used to group students based on their preferences in online and face-to-face learning environments. This model allows customization of materials and activities based on student behavioral data, significantly improving motivation and learning outcomes (Nguyen, 2022). In this context, Anwar et al., (2023) proposed a learning model that divides learning styles into four quadrants: Divergers (concrete experience and reflection), Assimilators (abstract thinking and reflection), Convergers (abstract thinking and active experimentation), and Accommodators (concrete experience and active experimentation). Each of these quadrants reflects a different way of processing information and interacting with the learning environment.

According to Soomro et al., (2023), there are three main types of learning styles, namely visual, auditory, and kinesthetic. In another study, Putra (2017) mentioned that learning styles consist of visual, auditory, reading/writing, and kinesthetic. Each style has different characteristics; for example, students with visual learning styles tend to understand material more easily through pictures and diagrams, while auditorial students prefer to listen to oral explanations, and kinesthetic students learn more effectively through physical activity and hands-on experience.

Learning styles refer to each individual's unique preferences in receiving, processing and interacting with information during learning activities. Various studies have revealed various categories of learning styles, including the following:

1. VAK (Visual, Auditory, and Kinesthetic) Style

   This model divides students based on their preference for visualization (pictures, graphs), sound (discussions, lectures), or physical activity (hands-on practice). Visual students tend to understand information through visual media, while kinesthetic students learn better by engaging in physical activities (Sood & Sarin, 2021). This model is important in personalized learning because it allows educators to design teaching strategies that suit students' learning styles, such as using visuals for visual students, discussions for auditory students, and hands-on practice for kinesthetic students, thus creating a more inclusive and effective learning experience.

2. Felder-Silvermen Learning Style Model (FLSM)

   This model categorizes learning styles based on four main dimensions: active-reflective, sensory-intuitive, visual-verbal, and order-global. It is often used in adaptive learning environments to tailor materials to students' needs (Usme et al., 2023). This model is particularly effective in adaptive learning as it allows for teaching tailored to individual learning styles. By understanding students' learning preferences through dimensions such as active-reflective, sensory-intuitive, visual-verbal, and sequence-global, educators can design a more personalized and appropriate approach, increasing student engagement and understanding. This approach allows material to be delivered in a way that best suits each student's preferences, such as using pictures for visual students or oral discussions for verbal students, which in turn facilitates more effective learning.

3. Kolb's Model

According to Kolb, learning styles involve a four-stage cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation. This model emphasizes on the way students integrate real experiences into the learning process (Ganira & Odundo, 2023). Kolb's model emphasizes that the learning process is not linear, but rather cyclical and dynamic, where individuals can move forward or backward between these stages according to their experiences and needs. Learning occurs continuously through the integration of real experiences, reflections, concepts and experiments. Each individual may have different preferences within this cycle, and therefore, understanding their learning style helps in creating a more effective and meaningful learning experience.

4. VARK (Visual, Auditory, Read/Write & Kinesthetic)

   VARK is a type of learning that is often used by many people to deepen understanding of material. This model is a development of VAK (Visual, Auditory, and Kinesthetic) by adding the reading/writing category. Students with this style tend to prefer learning through written notes or books, compared to visual or kinesthetic approaches (Sood & Sarin, 2021).

5. Social and Solitary Styles

   Students with the social type tend to learn more effectively when in groups or through discussions with others, as they feel motivated and gain better understanding through interaction and collaboration. They can share ideas, listen to different perspectives, and deepen their understanding of the material through shared discussions. In contrast, solitary students are more productive when they study alone, with full focus on the material and without external distractions. They tend to be more comfortable working independently, organizing their time and approach to learning according to personal needs, thus deepening understanding in a more in-depth and focused manner (Rashid et al., 2023).

METHODS

Research with a qualitative method using a literature review approach in this study aims to analyze various relevant literature related to adaptive e-learning systems based on learning styles. This method utilizes secondary data from trusted sources such as scientific journals, books, conference proceedings, and other literature sources to understand how e-learning systems can be adapted to individual learning styles, such as visual, auditory, or kinesthetic. In this approach, researchers gather information from various reliable sources such as scientific journals, books, conference proceedings, and research reports. The main focus is to critically evaluate the findings from the literature to identify trends, patterns and research gaps. The process involves selecting relevant literature, analyzing the content and methodology of previous studies, and synthesizing the information to find key themes that support the research objectives. This method is effective for building a strong theoretical foundation, providing comprehensive insights into the topic, and formulating recommendations for further research without requiring data collection.

RESULT

Definition and Components of an E-Learning System

An e-learning system is defined as a web-based platform that provides a virtual learning environment to support independent and flexible education. These systems usually include core components such as learning content management, user interface, and communication tools (Hao et al., 2007; Khan & Urrehman, 2013). According to Rezeki et al., (2023), e-learning system is defined as an information technology-based learning method that allows teaching and learning activities to be carried out flexibly, without time and place restrictions. It can be concluded that e-learning can be defined as an information technology-based learning system or method that provides a web-based virtual platform to support flexible and independent teaching and learning processes, without being limited by time and place. The platform includes core components such as learning content management, user interface, and communication tools to support interaction between teachers and learners. For example, e-learning can be explained as an educational medium that utilizes an online

platform to deliver learning materials, as well as support interaction between students, teachers, and materials through internet or intranet networks.

The system is designed to improve the efficiency and effectiveness of learning by providing quick access to educational materials, involving interactive features such as discussion forums, video conferencing, and web-based modules that can be customized to student needs (Pratama & Saputra, 2021). E-learning also enables online collaboration and gives students and teachers the flexibility to manage their own learning time (Yanti et al., 2022). Communication tools such as discussion forums, video conferencing and messaging systems support in-depth interaction, even if participants are in different locations. The flexibility offered by e-learning allows students to learn at their own pace and schedule, while teachers can structure materials and schedules to suit individual or group needs. It supports various learning styles, and provides automatic evaluation to effectively monitor progress. In addition, it can be resource-efficient with environmentally-friendly digital access.

E-learning systems are designed with various key components that work in harmony to create an efficient and effective learning experience. The integration of these components allows the learning process to take place optimally, ensuring that the needs of the various parties involved, such as students, teachers, and educational institutions, can be met. Each component is designed to complement each other, creating a synergy that supports flexibility, accessibility, and active engagement in learning. The main components of e-learning are as follows (Batara, 2021; Chang & Cheng, 2015):

1. Learning Management System (LMS) for organizing and delivering course content

   It functions to organize and deliver course content in a structured manner, as well as facilitate effective interaction between users, both in the form of communication between students and teachers, collaboration between students, as well as feedback that supports the learning process in a dynamic and integrated manner.

2. Communication tools such as discussion forums and chat rooms

   Includes features such as discussion forums and chat rooms that allow interaction between students and teachers, both synchronously through live conversations and asynchronously through written messages, thus facilitating flexible and in-depth communication in the learning process.

3. Assessment module for quizzes, assignments and exams

   Used to design, manage, and administer online quizzes, assignments, and exams, which not only enables structured and transparent evaluation, but also provides features to monitor students' learning progress in real-time, making it easier for teachers to provide appropriate and timely feedback and ensure students' engagement in the learning process.

4. Content repository for educational materials

   Provides access to a wide range of educational materials, including e-modules, learning videos, interactive documents, and other resources, which support flexible and independent learning for students, anywhere and anytime.

5. User management and authentication system

   Ensure access security through a strict user authentication process, which aims to manage and limit access rights based on their respective roles, such as students, teachers, and administrators, to protect personal data, learning materials, and ensure that only authorized parties can access certain features and information.

6. Analytic and reporting tools to track student progress

   The e-learning system helps monitor and track student learning progress in real-time, by providing comprehensive data on engagement, assignment achievement, quiz and exam results, which can be used to evaluate learning effectiveness and provide insights for improvement and customization of materials to better suit student needs and abilities.

The Role of Learning Style in Adaptivity

Learning styles have an important role in the development of adaptive learning systems, as they allow customization of materials and methods based on the unique needs of each individual. Research shows that identifying students' learning styles helps lecturers choose more effective learning models, creating a learning environment that is suitable for students' cognitive, affective, and psychomotor characteristics.

Learning style-oriented adaptive learning systems utilize technology to offer learning experiences that suit students' needs. For example, the development of web-based learning media with the principle of Universal Design of Learning (UDL) is able to provide various material formats such as modules, videos, audio, and images. With this approach, students can choose the method that best suits their learning style, which in turn significantly improves material comprehension (Cipto et al., 2022). This learning style adjustment in system design enables personalization, improves motivation, and student learning outcomes.

In the context of technology-based learning, this system can be integrated with artificial intelligence to detect student interaction patterns and provide relevant recommendations automatically. This technology enables real-time customization based on students' identified learning styles through analysis of data such as study duration, method chosen and level of engagement. This kind of customization provides greater flexibility for students, allowing them to learn in a way that is most effective for them.

From a psychological perspective, customizing learning to learning styles also plays a role in enhancing students' self-confidence and independence. When students feel that the learning process is aligned with their preferences, their motivation and engagement tend to increase. This is in line with research results showing that adaptive learning approaches that adjust to learning styles can create a more positive learning experience and motivate students to achieve higher results.

Overall, an understanding of learning styles is crucial in the development of adaptive learning systems. By utilizing a learning style-based approach, educational institutions can create a more inclusive, responsive and personalized learning experience. This not only improves learning outcomes but also helps students develop independent learning skills that will be useful beyond the formal education context. The combination of understanding learning styles, technology and adaptive learning principles is a significant step forward in creating a more effective and relevant education system.

The Problem-Based Learning (PBL) model, which is based on problem-solving principles, is particularly suitable for students with visual learning styles. In PBL, students are engaged in visually rich problem scenarios, such as diagrams, graphs or videos, which help them understand concepts in depth. Visual learning styles benefit greatly from this model because it focuses on visual representations, such as diagrams, graphs, and illustrations that can help organize information logically and think critically in solving problems creatively (Radiusman & Simanjuntak, 2020).

The Discovery Learning model is a pedagogical approach designed to encourage students to discover concepts and knowledge through active exploration. By providing space for students to learn independently, this model strengthens their engagement in learning and fosters a natural curiosity towards the material. This strengthens students' understanding of the material through an active and collaborative approach (Lestari & Munahefi, 2023). This approach supports visual and auditory learning styles by integrating diverse instructional media, such as videos, voice recordings and presentations. The application of technology in Discovery Learning through digital platforms such as learning apps and LMS extends its benefits by allowing students to explore the material independently, while getting feedback that supports understanding and error correction.

The PAKEM (Pembelajaran Aktif, Kreatif, Efektif, dan Menyenangkan) model or (Active, Creative, Effective and Fun Learning), a model designed for students with kinesthetic learning styles, creates more active and creative learning. Activities such as simulations, games and collaboration-based projects help students understand the material through physical experience.

The model is effective in increasing student engagement, especially those who tend to learn through physical interaction with their environment (Ubaidillah et al., 2023). This model prioritizes practical activities such as simulations, interactive games, and collaborative projects to increase student engagement and creativity, with teachers as facilitators who encourage the development of creative ideas, and technology enriches active learning, especially for students with kinesthetic and other learning styles, both inside and outside the classroom.

DISCUSSION

Relevance of Learning Style Preferences in E-Learning

Learning style is a key element in improving the effectiveness of adaptive e-learning, as each individual has a unique way of processing information. By utilizing models such as the Felder-Silverman Learning Style Model or VARK (Visual, Auditory, Reading/Writing, Kinesthetic),e-learning systems can customize learning materials according to user needs and preferences. This customization not only improves learning outcomes, but also student motivation and engagement in the learning process. Hariyanto et al., (2020) research shows that learning style-based adaptive e-learning system increases students' satisfaction by customizing materials based on their preferences.

The relevance of learning styles in e-learning today is increasingly significant, especially with the growing adoption of educational technology. Every student has different learning preferences visual, auditory, or kinesthetic and e-learning allows a more flexible approach to meet those needs. With features such as videos, interactive materials, and online quizzes, e-learning platforms are able to tailor the learning experience to individual learning styles. This is important in the context of education in Indonesia, where disparities in access and education infrastructure remain a challenge. The ability of e-learning to deliver personalized learning materials helps improve student motivation and learning outcomes, although it needs to be supported by adequate teacher training and technological infrastructure development (Aritantia et al., 2021; Nur et al., 2022; Sary et al., 2021).

A research study on the online learning system "Cybele" for cybersecurity education showed that personalizing the learning experience based on students' Myers-Briggs Type Indicator (MBTI) personality types resulted in improved performance compared to traditional learning methods (Samonte et al., 2023). Individual learning styles have a significant influence in determining perceptions and attitudes towards online learning. Mohr et al., (2012) research shows that learning styles, with other factors such as professional experience, contribute to the perceived usefulness of online learning tools and attitudes towards virtual environments. This confirms the importance of designing online learning platforms that are adaptive to learning styles to increase user effectiveness and convenience.

Learning style refers to an individual's preference in understanding, processing and remembering information. In the context of e-learning, learning styles play an important role in determining the effectiveness of digital learning to support each individual. In e-learning, materials tailored to students' learning styles can increase motivation, engagement and comprehension. E-learning systems can identify students' learning styles based on their responses to learning materials and customize content to support learner preferences.

According to Krasodomska & Godawska (2021) adapting learning content to students' learning styles significantly improves academic outcomes. Adaptive technologies, such as artificial intelligence-based algorithms, can recognize students' learning styles and adjust content accordingly. The study involved Bloom's Taxonomy and showed that personalization helped reduce dropout rates significantly (Yousaf et al., 2023). This is equivalent to the research of Hassan et al., (2021) that it was shown to reduce dropout rates by 26% and increase engagement by 25%. In addition, Ergün & Adıbatmaz (2020) research shows that students who receive materials that match their learning style perceptions tend to be more active in e-learning participation and show better academic results.

Effectiveness of Adaptive E-Learning Based on Learning Style

Adaptive e-learning systems that personalize content based on learner characteristics, including learning styles, have shown promising results in improving learning outcomes and learner satisfaction. Several studies have shown the effectiveness of these systems in improving the performance of e-learning experiences compared to traditional learning methods (El-Sabagh, 2021; Rishard et al., 2022; Samonte et al., 2023).

The effectiveness of e-learning today has been proven by the presence of several learning technology innovations that allow flexibility, personalization and wider access, for example the "Adaptivo" system developed by Rishard et al., (2022) which presents a fully personalized learning path, tailored to the learning style and knowledge level of individual learners. As a result, it significantly improves learning performance and satisfaction. Meanwhile, "Cybele," as described by Samonte et al., (2023), takes a unique approach by utilizing the Myers-Briggs Type Indicator (MBTI) personality model to design learning experiences that are aligned with users' learning styles. This innovative approach is proven to result in much better learning performance than traditional methods, making it a revolutionary step in the world of e-education.

In addition, adaptive-based platforms such as Google Classroom and Edmodo have been designed to support individual learning styles with features such as collaborative assignments, interactive multimedia, and project-based simulations. Research shows that these platforms not only improve students' understanding but are also able to motivate students to learn more independently, especially during the COVID-19 pandemic when online learning is a major necessity (Putra et al., 2022). These features not only improve students' concept understanding but also help create a more engaging and participatory learning atmosphere. The integration of these technologies shows how adaptive e-learning can be an effective solution in improving the quality of education, even in conditions of physical restrictions. The implementation of this technology proves that digital-based education is not only able to replace conventional methods but also brings new opportunities to support more flexible and personalized learning.

The "Merdeka Belajar" system as a new learning curriculum introduced by the Indonesian Ministry of Education has created and promoted a pleasant learning atmosphere and aims to develop analytical skills and comprehensive understanding, not just memorization (Rahmawati & Rahmawati, 2020). The system seeks to realize education that is humanistic, relevant to the needs of the times, and creates graduates with 21st century skills. This is in line with the objectives of the adaptive e-learning system. Strategic methods to achieve this include blended learning, STEAM (Science, Technology, Engineering, Arts, and Mathematics), and electronic learning management systems.

The results of this study confirm the importance of adapting e-learning systems to meet diverse learning needs, integrating learning styles as one of the key factors. The findings also show the great potential of e-learning to improve learning outcomes in a more individualized and effective manner, given its ability to customize materials according to learners' uniqueness. With the development of technology and the increasing use of e-learning in education, customizing learning materials based on individual learning styles has great potential to overcome the challenges of conventional learning. It enables a more inclusive and holistic learning experience, and provides opportunities for learners to achieve more optimal results according to their unique learning styles.

CONCLUSION

Learning style-based adaptive e-learning system is an innovative approach in education that aims to improve learning effectiveness by customizing materials and delivery methods according to learners' individual characteristics. Research shows the importance of adaptation in e-learning systems by considering learners' learning styles, knowledge levels, and interests to improve academic performance and satisfaction with the learning process. However, the development of these systems faces significant challenges in terms of the accuracy of student learning style identification and the effectiveness of adaptive interventions. To overcome these obstacles, further

research and development is needed by utilizing artificial intelligence technology to improve the accuracy of the algorithm and optimize the infrastructure.

Based on the analysis of various learning style approaches, this study found that e-learning systems that are able to adapt to auditory, visual, and kinesthetic learning styles tend to increase learner engagement and learning outcomes. In addition, flexibility in the arrangement of learning materials and methods tailored to each learning style preference, strengthens the effectiveness of the learning process. This research also highlights the importance of applying advanced technology to support the development of a responsive and dynamic e-learning system, which can enhance the overall learning experience. As a suggestion, the implementation of adaptive e-learning system should pay attention to more in-depth personalization aspects, as well as the development of features that support the diversity of learning styles, especially in online learning.

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