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The Role of AI-based Adaptive Learning Systems in Digital Education

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Abstract: *The application of AI-based adaptive learning systems is an important innovation in educational technology offering efficient and personalized learning experiences. The potential advantages of learning with AI support are significant besides the various challenges and limitations that should also be considered. The future of this new wave in education is promising, as it can transform and improve learning outcomes for students. As technology progresses, these systems will become more sophisticated, possibly offering more extensive opportunities for personalized education. This research gives an overview of the implementation of AI-based adaptive learning systems focusing on the advantages. The paper foresees the visualized practical use of AI in the process of learning and teaching as a helpful tool in digital education and discusses the key aspects of its use.*

Keywords: *Artificial Intelligence; adaptive learning; AI-based adaptive learning; digital education; machine learning*

1. Introduction

Digital education has rapidly become a significant and now an indispensable methodological feature of current educational procedures and the concept is referred to as the new paradigm in education. (Kilicoglu & Kilicoglu, 2020), (Mhlanga 2023) According to Szűts, digital pedagogy simultaneously states the relation to technique, communication, media, and pedagogy. In his interpretation, digital pedagogy is a unit of classroom or distance learning methodologies, ways of thinking, organizational processes, and forms of work based on info-communication devices, screens, databases and digital content. (Szűts, 2020) In the comprehensive view by Lengsfeld, digital education is the formation of an individual in the sense of a comprehensive and holistic spiritual, physical, social, and cultural development into a reflected person aware of every side of his or her being as a human in a digital world and is able to draw conclusions for the shaping of his or her life in the digital age based on this. The term 'digital education' is also

instrumentally used in his approach. In this respect, digital education is seen as a process of education that is supported, made possible, or shaped by the use of digital information and communication technologies. (Lengsfeld, 2019) Leveraging technology to the classroom, digital pedagogy extends the limitations of traditional education with flexibility, accessibility and opportunities for personalized learning. From online courses and virtual classes to interactive educational applications and multimedia resources, digital education includes a wide range of tools and platforms that create new opportunities to make learning and teaching enhanced. It is a transformative way of education, as it not only caters to different learning styles and paces, but also removes geographical barriers leading to the access to quality education worldwide. As the result of the continuous advancement of digital education, learning has become democratic, lifelong, and the skills from digital learning enabled students to thrive in the progressively digital world.

In recent years, Artificial Intelligence (AI) has emerged in and revolutionized various sectors of our lives including the field of education, too. The appearance of AI in digital education manifests in different forms and applications, changing the way of learning and teaching, i. e. the role of the student and the teacher in the learning process. These AI-based learning systems have emerged as potent tools in digital education with innovative solutions to improve teaching and learning experience. These systems basically work on advanced algorithms and are able to perform data analysis to provide a personalized learning experience, automate administrative tasks and insights into student performance. AI-based learning systems adapt to individual learning styles and needs and dramatically change traditional educational paradigms creating a more inclusive, efficient and engaging learning environment. (Tuomi, 2020)

2. AI-based adaptive learning systems

AI-based adaptive learning systems refer to those educational technologies that use artificial intelligence to personalize learning experience considering the needs of individual students. The systems collect and analyse information related to student performance, learning preferences and progress to create personalized learning pathways. Therefore, in modern education, adaptive learning is of paramount importance addressing students' diversified needs, keeping learners engaged and improving learning results. The basic premise of adaptive learning systems lies in their ability to capture a huge volume of data on student performance, behaviour, preference and interactions with the material. The measured data is analysed based on advanced analytics techniques to help understand and draw conclusions about the learning

process. At the core of adaptive learning systems, machine learning algorithms can be found. These algorithms can analyse the received data, detect patterns, predict future performance and recognise the most effective way in which each individual student learns. The use of machine learning ensures that the efficiency of the system can continuously be enhanced as it adapts to the changing needs of students. Based on the gained data insights, adaptive learning systems create personal learning pathways for each student. This would then ensure that both the content and pace are ideally designed to suit the individual learning preferences and abilities for a more efficient and interesting learning experience. One of the significant advantages of adaptive learning systems is real-time feedback that students receive based on their performance in order to give information about their strengths and weaknesses, thus allowing for correction in learning strategies when needed. This constant feedback is crucial, as it cultivates self-directed learning and self-improvement. (Ezzaim et al, 2022), (Arroub et al, 2020), (Chen et al, 2020)

There are other important benefits of adaptive learning systems. Catering to the individual needs of each student by providing personalized learning experience is a key feature as well, which can evoke better understanding and application of knowledge. Adaptive learning systems can engage and motivate students by providing relevant and appropriately challenging content. The attention and motivation of students can be kept continuously throughout their studies when the learning content is adaptive to their level of performance and interest. Research has shown that adaptive learning can lead to tremendous improvement in learning results. The adaptive learning systems can help close the learning gaps and ensure each student reaches the best of their potential by focusing on the specific needs of individual students. Besides, AI-based adaptive learning systems can cater for a large number of students, making quality education available for those in need. (Verdú Pérez et al, 2008), (Contrino et al, 2024), (Chen et al, 2020)

Scalability makes these systems crucial for addressing educational disparities and providing access to personalized learning opportunities for students. Another significant advantage includes catering to a differentiated kind of instruction, which is rare in the usual classroom settings. Differentiated instruction is an approach where teachers adjust their teaching approaches and materials to suit the various styles, abilities and interests found among students. Adaptive learning systems automate this process by continually assessing the progress of a student and dynamically changing the instructional content. This proceeding can help both teachers and students, especially in a diverse class where the prior knowledge and learning speed of students are different. (Wang & Hannafin, 2005), (Chen et al, 2020), (Bakhshinategh, 2018)

Furthermore, adaptive learning systems provide information for teachers about student performance, and they can use the received data to identify students who may be lagging behind and in need of support, or to recognize students who are excelling and need more challenging content. This saves instructional time, hence achieving more within a limited period. Adaptive learning systems not only enhance the individual learning outcome but also forms collaboration among learners. Through the identification of students with the same learning needs or those whose skills are complementary, these systems can enable group activities and further peer learning. Working in groups not only enhances one's understanding through discussion and interaction, but also aids in developing the soft skills of students such as communication, teamwork and problem solving. (Steenbergen & Cooper, 2014), (Chen et al, 2020), (Bakhshinategh, 2018)

Though they have promising advantages, there are some challenges faced by AI adaptive learning systems, too. Apart from the emerging questions of its ethical use, one major concern is the possibility of creating technological dependence if both students and teachers become too reliant on adaptive systems to the detriment of other forms of learning and basic elements of critical thinking. There must be a balance between the use of technology and other instructional techniques so that students receive a comprehensive education. In addition, though adaptive learning systems can offer individualized instruction, they sometimes lack the sophistication of human teaching. Factors such as the emotional and social dimensions of learning, which play an important role in student engagement and motivation, cannot be easily measured and incorporated into adaptive algorithms. This makes integration with holistic educational practice very important because the wider context of student development also needs to be considered. (Verdú Pérez et al, 2008), (Contrino et al, 2024)

Another area of concern is the digital divide, the gap between technology and internet access for some and a lack of such for others. These inequality reasons are what might probably render it impossible for students in underprivileged or rural areas to access to any adaptive learning system, hence creating more division in educational outcomes. This factor requires some level of responsibility from policymakers, educational institutions, and stakeholders who provide technologies to ensure that there is equitable access to digital learning resources. The advantages and disadvantages of an adaptive learning system can be maximized and minimized, respectively, through research and development. Further advancements in machine learning algorithms make them less biased with increased data privacy, security and incorporating friendly interfaces for both educators and students. In addition, there must be a culture of

continuous improvement and feedback in learning institutions as part and parcel of integrating adaptive learning systems. (Ezzaim et al, 2022), (Arroub et al, 2020)

The introduction of adaptive learning systems requires adequate technical infrastructure and expertise. The implementation of such systems may be difficult for educational institutions due to the cost of acquiring the resources and training the staff to support their use. Traditional educational institutions may be conservative in terms of adapting to new technologies and changing established practices in teaching. The way of overcoming possible resistance include provisions for the value and effectiveness of the adaptive learning systems and support for educators during implementation. AI-based adaptive learning systems has the potential to revolutionize education technology. These systems could really enhance student outcomes and engagement by personalizing the learning experience through real-time feedback. However, it will become imperative to meet challenges related to data privacy, bias and access to technology for systems of adaptive learning implementation to actually work effectively and fairly.

3. The key features of the presence of AI in digital education

Some of the major aspects of AI in digital education are advanced personalized learning environments, intelligent tutoring systems, content creation and curation, advanced engagement tools, language processing tools, accessibility and inclusion, and teacher support systems.

1. Personalized learning environments

- Adaptive learning platforms: The use of AI technologies to change the level of difficulty and even genre of content based on the performance level and speed of learning of a particular student. In most cases, there is a provision for an interface with which the student can interact through the lessons and quizzes that are meant for independent learning as well as actual practice.
- Learning analytics dashboards: Graphical displays of students' progress such as their strengths and areas that need improvement. Mostly, these visual displays are in the form of graphs and charts for clear understanding.

2. Intelligent tutoring systems

- Virtual teachers and assistants: AI tutors are used to provide one-on-one support, answer questions, and make explanations on various topics. They normally appear as chatbots or animated characters.
- Automated feedback and grading: It is provided for systems that offer instant feedback on tests and performance by pointing out the mistakes and indicating how student achievement can be improved.

3. Content creation and curation

- AI-generated content: Systems that produce learning items, such as practice questions, flashcards and summaries from the curriculum data.
- Smart resource recommendations: The algorithms suggest more or better sources of learning materials and resources that is adjusted to the level, need and interest of students.

4. Engagement tools

- Gamification tools: Game-based, AI-driven learning platforms have potential to engage and motivate students, where they can score some points, win badges, and get into a leaderboard ranking system.
- Interactive simulations and virtual labs: AI-powered environments which enable students to perform experiments and simulations that will allow them to virtually experience a hands-on learning process.

5. Language processing tools

- Language translation and transcription: AI tools that perform the translation of the educational content into different languages and its real-time transcription in delivering lectures and discussions.
- Natural language processing for writing support: Using NLP technologies in enhancing a student's writing by suggesting the corrections made in grammar, style, or plagiarism.

6. Accessibility and inclusion

- Speech-to-Text and Text-to-Speech: AI technology that interprets spoken language into text and vice versa, thereby helping students with disabilities.
- Adaptive earning interfaces: These programs adjust the size of fonts, colour contrasts and layouts for each student with respect to their learning needs, whether in visual or cognitive terms.

7. Teacher support systems

- Professional development: AI-driven platforms offering personalized learning paths for teachers to develop new skills and stay updated with educational trends.
- Classroom management tools: The AI-related tools that would be of major importance in assisting a teacher's activities would include tracking attendance and monitoring students' activities, behaviour and interaction.

4. The possible visualization of AI in digital education

A picture of a new kind of classroom, where artificial intelligence is embedded in digital education, includes an efficient learning atmosphere that is dynamic, inclusive and supportive. The possible visualization of the image of the application of AI support might feature students interacting with tablets or laptops using an adaptive learning platform with the screen showing personalized lessons that each student receives, based on performance data, preferences and progress on an individual learning path. The AI-based virtual tutor avatar will guide students through complex topics with explanations and instant feedback. This virtual tutor changes its teaching style according to the engagement of students for an even more effective and interesting experience. (Popenici & Kerr, 2017)

The classroom is itself a centre of smart technology. Smartboards are used instead of old chalkboards and show dynamic information that the teachers may control on time to support or portray lessons more clearly. Many connected devices are alternately available in classrooms for students and teachers to get access to digital resources. This is not just limited to tablets and laptops but includes VR headsets for an immersive learning experience and IoT devices that make the lessons interactive.

Teachers can monitor the real-time progress of students by using AI-driven dashboards containing data from sources offering clear insights to performance. They bring into relief the areas that students are good in and areas that might need improvement and, therefore, enable teachers to intervene effectively and in time. Such insights happen in real-time; this assures timely learning interventions based on the very latest data. (Persico & Pozzi, 2015)

In this image, we see a varied group of students, each using different AI tools that cater to their specific learning needs and interests. Some students use language-translation apps to break the language barrier and be able to consider learning contexts. Others have virtual labs where they can do experiments and explore scientific concepts in a controlled, simulated setting. The

interactive games, which are also part of the lesson, capture the attention of students by making a relatively dull activity interesting or are used as checking for understanding or practice.

The realization of this image would require in-service trainings for teachers on how to use AI tools for improving their teaching methods, making their lessons engaging and keeping students motivated. Such tools empower teachers with personalized learning pathways and resources that continually assist in revolutionizing their educational strategies. The AI analytics help teachers understand the impact of their practices and those areas where they can change for improvement.

This image clearly illustrates the broad adoption of AI technologies in education. This illustrates how AI personalizes the learning experience not only for the students, but also for teachers with high-quality teaching. The classroom is a place where traditional teaching methods are spiked with state-of-the-art technology, hence striking the proper balance of paying respect to the foundations of education and pushing the boundaries. In other words, AI images in digital education lean towards a learning atmosphere created with the integration of technology into human creativity in an adaptive, inclusive and very effective learning environment. All of these visualized features can benefit learners and at the same time empower teachers to make the journey through education a more collaborative and personalized experience. (Khosravi & Cooper, 2017)

5. The AI-based adaptive learning systems framework

According to the above presented study, the framework of the AI-based adaptive learning systems can be established based on the advantages as shown in Figure 1.

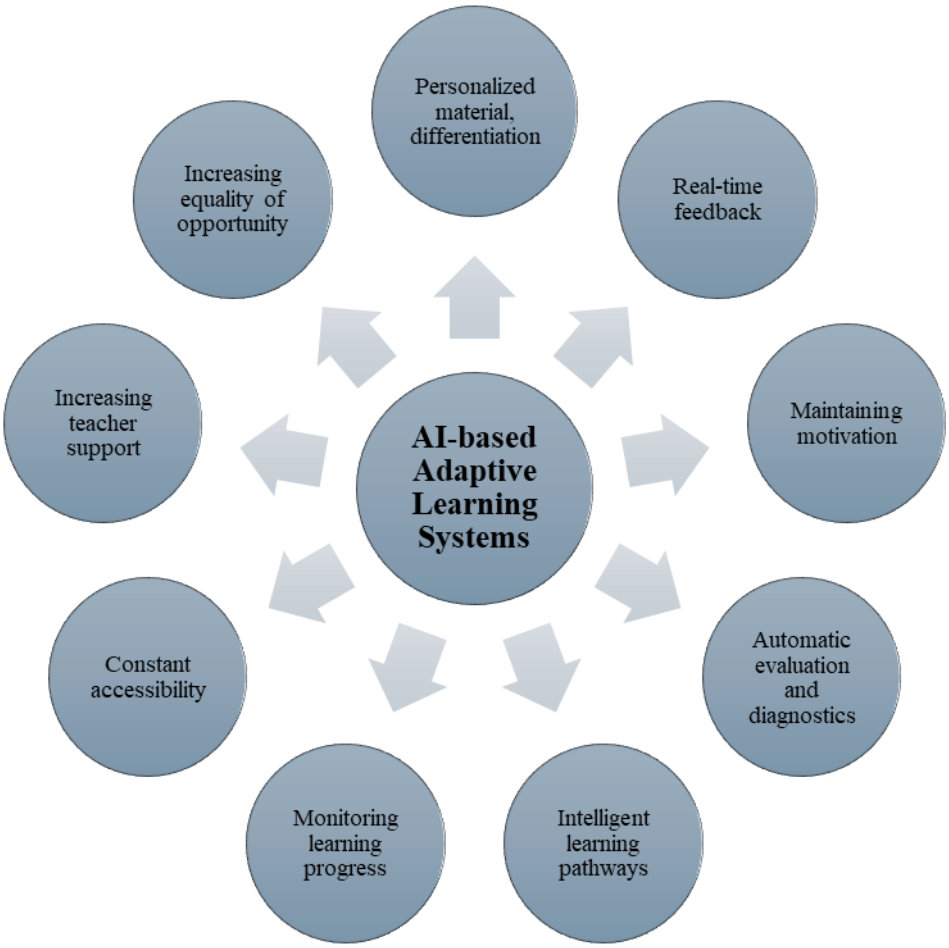

Figure 1. The AI-based adaptive learning systems framework

1. Personalized material or learning and differentiation: through AI the customization of educational content and learning approaches in a way that is more in tune with the preferences and needs of individual learners can be achieved. Differentiated groups can be better detected in regard to learning styles, strengths, weaknesses, and preferences, focusing on closer, more effective and personal learning experiences.

2. Real-time feedback: AI can provide instant feedback to students, which could help them realize errors and learn from them immediately. This would allow teachers to be able to offer interventions and support on time.

3. Maintaining motivation: AI can be used to create engaging, personalized and supportive learning experiences that keep students motivated. Techniques and tools that aim to leverage AI to keep motivation include personalized learning paths, gamification, real-time feedback and rewards, adaptive assessment, interactive content, social learning and collaboration, goal setting and progress tracking.

4. Automatic evaluation and diagnostics: AI in education is implemented to automatically assess and diagnose student performance, provide feedback, and spot learning gaps or areas of imperfection. AI can grade and assess automatically, leaving the teacher more time for other duties and providing the students with immediate feedback.

5. Intelligent learning pathways: ILP, with the help of AI and data analytics, will dynamically be able to adapt the content, pacing, and style of learning materials to optimize learning results. These pathways offering personalized learning experiences that are capable of significantly enhancing engagement and thus, effectiveness, are essential in today's education and corporate training environments.

6. Monitoring learning progress: Teachers can monitor learning progress by leveraging the data analytical skills, pattern recognition and predictive analysis into student performance provided by AI and thus, they can customize learning experiences. This would enable the learning progress to be monitored in real time and continuously, allowing for interventions or student support to be put in place.

7. Constant accessibility: Students can have continuous support, learning material and opportunities due to the constant accessibility ensured by AI without regard to time or location. AI, unlike human teachers, is always available for students and can be constantly productive.

8. Increasing teacher support: AI might be used to enhance teacher support, without any claim to completeness, including administrative duties, lesson plans, managing classroom behaviour, automatic grading and testing. Thanks to the AI-based support, teachers can focus more on other important factors of their profession, for example, giving students the personal touch or building community in the classroom.

9. Increasing equality of opportunity: AI could be used in increasing equality of opportunity in education as it would help solve existing disparities in access, learning experiences and support by personalizing the learning experience for all students.

6. Summary

AI-based adaptive learning systems can be integrated with traditional learning environments to support teaching and learning in the educational experience. In this hybrid approach, the maintenance of the structure and social benefits of traditional classroom settings would be combined with the AI-supported personalized learning. The field of adaptive learning is rapidly evolving, with emerging new trends and technologies. These include bringing forward

advanced natural language processing to evoke improvements in interaction, the inclusion of virtual and augmented reality to create more immersive learning experiences and developing more sophisticated algorithms to increase personalization. Further developments of artificial intelligence tools and machine learning will probably continue to transform adaptive learning systems. Advancements in data analytics, predictive modelling and personalization algorithms will lead to a more efficient and engaging learning experience. Although AI-based adaptive learning is spreading, the role of educators, who adapt to new technologies and utilize them during teaching, remains crucial. Teachers have an important role in guiding and supporting students in the process of education, where technology facilitates rather than replaces human interaction and mentorship.

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