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The Application of Artificial Intelligence in Intelligent Tutoring and Adaptive Learning

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***Abstract*: Artificial intelligence tools have been widely integrated into the field of education and training because of their potential benefits in terms of enhancing students' learning process. This study provides a literature review on the application of artificial intelligence in learning, including intelligent tutoring and adaptive learning. Recent implementation of artificial intelligence tools supporting intelligent tutoring and adaptive learning in various learning activities are discussed. In addition, this research provides insights into the current trends and future directions for leveraging artificial intelligence that can facilitate the learning experience, especially explainable artificial intelligence and personalisation.**

***Keywords*: Artificial Intelligence, adaptive learning, education, intelligent tutoring.**

1. Introduction

Artificial Intelligence (AI) has gained billions of dollars of investment annually because of its tremendous impact on the way humans live, work, study, and so on. There is a consensus that AI has been embedded in the educational environment and affects various activities such as learning, teaching, and management. (Chen et al., 2020). Previous research suggested that AI tools can be used to enhance the learning experience, promote the enthusiasm toward learning, and increase the learning progress (Yang & Bai, 2020). AI can also support teachers in their teaching process and make their classroom management more efficient (Wang, 2021). Moreover, AI has advanced significantly because of the rapid development of science and technology. It can be argued that AI tools will become more useful in terms of supporting learning and teaching activities. The adequate development of AI and its appropriate integration in learning and teaching can potentially transform the field of education.

Currently, many countries are committed to supporting the use of technology, especially AI, to improve teaching and learning, as well as to support innovation throughout educational technology systems (edtech) (Rodriguez-Segura, 2022). A system is considered as edtech if it includes both technologies specifically designed for educational use and general technologies that are widely used in educational settings. AI technology needs to be able to capture and detect patterns in data and to provide access to instructional resources to automate decisions about instruction and other educational processes. Detecting patterns and automating decisions are leaps in the level of responsibilities that can be delegated to a computer system. However, the process of developing an AI system may lead to bias in how patterns are detected and unfairness in how decisions are automated. Therefore, edtech must govern their use of AI systems to control its quality.

2. Artificial Intelligence in Learning

According to Yannier & Koedinger (2020), it is beneficial to assist students to become active learners. Students should be encouraged to join in discussions that enhance their understanding. Also, students should be provided with the implementation of simulations and visualisations to facilitate their learning as they can link learned topics to real-world situations. In addition, their learning can be leveraged when receiving timely and relevant feedback during their learning process. It is reasonable to tailor educational technologies to suit and facilitate active learning. Therefore, the development and implementation of AI-enhanced educational technologies should be able to promote the active learning of individuals, especially those who have faced unfavourable learning conditions.

Previous research has shown various successful examples of the use of AI in supporting active learning principles. For instance, based on theories related to cognitive learning, AI tools can be considered as online tutors when students need to seek answers or solve problems (Bassner et al., 2024). This study highlighted that learners are likely to use AI tutors to avoid any judgements from their peers. Regarding theories related to the "Computer Supported Collaborative Learning," AI applications can be used to facilitate effective group learning (Hidalgo et al., 2023). AI can also be adapted to assist learners having special needs, which is referred to as the "Universal Design for Learning framework" (McMahon & Walker, 2019). Furthermore, Huang et al. (2021) suggested that AI can play a key role in promoting the learning experience by providing adaptive learning and intelligent tutoring environments.

3. Artificial Intelligence Supporting Intelligent Tutoring

A. Application of Artificial Intelligence in Intelligent Tutoring

According to Mousavinasab et al. (2021), Intelligent Tutoring Systems (ITS) are one well-known example of AI-

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enabled technology. Researchers were able to create precise models of how human specialists solve mathematical problems in an early success. The final model was integrated into a system designed to watch students solve difficulties while using a computer to solve mathematical problems. Studying human instructors, researchers discovered that part of the reason tutoring works so well is probably because the tutors provide feedback on various stages rather than just correct or wrong answers (VanLehn, 2011). For instance, the system provided feedback to a learner who deviated from the expert model to assist them in getting back on course. Crucially, the model was able to offer feedback on certain phases in a solution process, going beyond simple right or wrong (Ritter et al., 2007). Therefore, the capacity of AI to provide adaptivity at the step-by-step level and to do so at scale with low cost can be considered a significant achievement in AI.

Since the field of research and development emerged to advance ITS, the work has gone beyond mathematics problems to additional critical issues beyond step-by-step problem solving. There are certain limits to early work. An ITS might handle logical or mathematical issues that were closed tasks with explicit expectations for the solution and solution process. Furthermore, the "approximation of reality" in early AI models was limited to cognition rather than other components of human learning, such as social or motivational factors. These early constraints have been overcome in two ways: by extending AI models and putting humans in the loop, which is still relevant today. For example, if an ITS focuses on feedback as a student practice, a human instructor may still be responsible for inspiring student engagement and self-regulation, among other components of education. In more recent examples, computer ITS may focus on problem-solving practice, while teachers interact with students in small groups. Furthermore, "open learner models", which is a sort of AI-enabled system that gives information to promote student self-monitoring and reflection, allow students to be involved in the AI process (Winne, 2021).

B. Directions of Artificial Intelligence in Intelligent Tutoring

AI holds significant potential for enhancing intelligent tutoring systems (ITS) and improving the educational experience. Previous research has provided insights into the future directions for AI in intelligent tutoring. One potential direction is the development and implementation of explainable artificial intelligence (XAI) in education, especially intelligent tutoring. According to Arrieta et al. (2020), XAI refers to the creations of machine learning techniques that can make adequate models in terms of explainability so that people can understand, trust, and manage answers generated from them. By doing so, XAI can reduce the concerns from students (as well as teachers) when they utilise AI tools in their learning. Besides, Shneiderman (2020) proposed a framework called Human-Centered Artificial Intelligence (HCAI), which should be implemented when developing safe, trustworthy, and reliable AI tools. The framework suggests the balance between controls from human and computer to enhance both human performance and computer automation.

Regarding the learning process, Silva et al. (2022) suggested that e-learning platforms for tutoring should focus on improving learners' engagement through the provision of lecture summarisation, interactive mind maps, and insightful evaluation. Lin and Mubarok (2021) pointed out the importance of enhancing learning interaction between learners and robots by implementing personalised AI chatbots, which in turn increases learning performance. In addition, the application of intelligent tutoring requires the development of new educational theories focusing on increasing students' interest in terms of learning. For example, Chan et al. (2018) suggested a fundamental shift from an examination-focused to an interest-focused instruction style and proposed the Interest-Driven Creator (IDC) Theory. This theory suggests that adequate learning activities supported by emerging technology (such as AI) can help students develop learning interest, which promotes their daily learning activities and reinforces their creative habits.

4. Artificial Intelligence Supporting Adaptive Learning

A. Application of Artificial Intelligence in Adaptive Learning

Adaptivity has been considered as a crucial method in which technology might enhance learning (Aleven et al., 2016). AI may be used to improve the adaptivity of educational technologies. AI might increase a technology's capacity to meet students where they are, capitalise on their strengths, and expand their knowledge and abilities. Because of AI's ability to deal with natural forms of input and the basic characteristics of AI models, AI can be an exceptionally effective toolset for increasing students' adaptivity.

However, adaptivity, particularly with AI, is always more specialised and constrained than a general term like "meet students where they are" may imply. Core limitations originate from the nature of the model at the centre of any AI-enabled system. Models are approximations of reality. When crucial aspects of human learning are left out or underdeveloped in the model, adaptivity suffers, and learning supports become brittle or restricted. As a result, it is important to develop AI tools that can facilitate the whole learning process of students.

AI models are displaying better skills because of developments in "large language models" or "foundational models." These highly generic models nonetheless have limitations. For example, generative AI models featured in the mainstream media may swiftly generate convincing articles on a wide range of themes, but other models can create plausible visuals with only a few cues. Despite the enthusiasm around basic models, experts in our listening sessions cautioned that AI models are narrower than aspirations for human learning, and that creating learning environments with these constraints in mind is critical. The models are also fragile and do not function well when the context changes. Furthermore, they lack the same "common sense" judgement as humans, resulting in strange or inappropriate responses (Dieterle et al., 2024). Given the unforeseen ways in which basic models fall short, having people involved is critical.

B. Directions for Increasing AI-Based Adaptivity

According to Plass and Pawar (2020), one direction to increase the adaptivity of AI tools is promoting personalisation in learning. Various methods can be applied to enhance personalisation, such as the provision of human-robot interaction during learning or the arrangement of learning activities that are personalised to each learner. Changing the difficulty and arrangement of course materials are typical ways that edtech products adapt to personalise the learning process. However, it is important to recognised that there are other ways to facilitate learning rather than simply altering the complexity and sequencing of information. For example, a competent teacher may engage a student by relating to their own prior experiences and shaping explanations until they truly connect, resulting in an “eureka” moment for that student. In addition, human teachers can provide a more comprehensive view on the learning progress of students than most AI tools.

Previous research suggested several ways to extend AI systems to enhance the adaptivity (Chen et al., 2020, Zhai et al., 2021). During the listening session, speakers remarked that the rhetoric around adaptivity has frequently been deficit-based. Technology aims to identify a student's weaknesses and give targeted training to address them. Teachers focus on students' strengths, identifying and using their talents to enhance their learning. Equitable AI models must recognise and build on each student's sources of competency. Developing AI models that prioritise assets would be a significant advancement.

Adaptivity rhetoric has mostly emphasised individualised learning and cognitive aspects, with motivational and other factors added to assist these aims. Attendees have a larger perspective for learning than just cognitive abilities. Social learning is vital, for example, in teaching pupils to reason, explain, and justify. For students learning English, personalised and adaptive help for strengthening language skills while studying curricular content is plainly vital. It is also vital to work on self-regulation abilities. A modern concept of learning is not individualistic; it acknowledges that kids learn in groups and communities.

In addition, AI models can aid neurodiverse learners, who engage with the environment in unique ways compared to "neurotypical" pupils. They may benefit from distinct learning routes and display formats that align with their strengths. Constituents desire AI models that facilitate learning for neurodiverse and disabled learners. Moreover, AI tools should be adaptable to various learning routes and modes of engagement. Models should be checked for effectiveness to avoid assigning insufficient learning resources to certain pupils. Designing systems for neurodiverse students should promote their intended usage, as certain solutions are currently underutilised.

Many adaptivity systems rely on a model that assesses students' incorrect responses and determines whether to speed up, slow down, or provide more learning help. However, learning objectives do not merely include correct and incorrect responses. It is crucial for students to learn how to self-regulate when they face learning challenges, such as being able to persevere in working on a tough problem or understanding when and how to seek assistance. As students mature, they should be able to have greater agency and be able to act independently to achieve their own learning goals.

5. Limitations of the Use of Artificial Intelligence in Learning

As AI has been integrated into the educational system, it is important to recognise and mitigate limitations of the use of AI in learning. Bozkurt (2021) suggested that the use of AI in unstable or unpredictable learning context should be employed with extreme caution. AI systems and tools do not completely fit with learning goals, it is beneficial to develop educational contexts that allow educators and other adults to effectively use these technologies for teaching and learning. Regarding the Intelligent Tutoring Systems, although AI may improve learning by helping students solve math problems, a more comprehensive approach should include teacher responsibilities to emphasise mathematical techniques such as reasoning and modelling. Furthermore, small-group work is expected to remain important: students may work in small groups to apply mathematics to forecast or justify their responses to a real-world difficulty. Now, one "right place" for people, rather than AI, is to understand how learning can be culturally responsive and culturally sustaining, as AI is still a long way from being ready to connect learning to a student's specific strengths in their culture and family.

6. Conclusion

The application of AI to create an intelligent tutoring and adaptivity environments has been discussed. It is important to develop AI tools that can personalise learning experience and closely fit with learning objectives. AI is quickly evolving so this requirement can be used as a reference to discern between goods with simple AI-like characteristics and those with more powerful AI models. Looking at what is going on in research and development, significant work needs to be done to make the use of AI more beneficial in education. It is noticeable that because general artificial intelligence does not exist, decision makers must exercise caution when picking AI models that may limit their vision for learning. In addition, the overall learning system is more than just the AI component. Because AI models will always be narrower than real-world experience, one potential direction is systems thinking that includes people and considers the strengths and shortcomings of the unique educational system.

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