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PERSPECTIVE

Educational Technology in the University: A Comprehensive Look at the Role of a Professor and Artificial Intelligence

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ABSTRACT This study aims to delineate the roles of professors at universities and explore the educational applications of Artificial Intelligence (AI). With rapid advancements in AI technology, there is an increasing effort to integrate AI and Educational Technology (EdTech) into educational practices, resulting in AI EdTech. Higher education institutions, particularly universities, are focused on leveraging AI EdTech to augment traditional teaching roles. Traditional educational methods often face limitations in providing personalized learning experiences, whereas AI EdTech offers promising solutions to enhance these methods and provide immersive learning opportunities for students. Currently, various universities independently pursue the implementation of AI EdTech. However, for AI EdTech to be successfully established and widely adopted in higher education, key factors such as maintenance costs and the potential for continuous development should be considered. Therefore, the standardization and development of AI EdTech systems that can be universally applied across universities are essential. In this regard, this study defines the core roles of professors and proposes developmental levels for AI professors to complement these roles. It also outlines the necessary Key Performance Indicators (KPIs) for each level of AI professor development. These initiatives are expected to play a crucial role in the future standardization and research development of AI EdTech systems.

INDEX TERMS Artificial intelligence (AI), educational technology (EdTech), intelligent tutoring system (ITS), large language model (LLM), human-in-the-loop (HITL), technological pedagogical and content knowledge (TPACK), key performance indicator (KPI), universal design for learning (UDL).

I. INTRODUCTION

The advent of Artificial Intelligence (AI) has brought significant innovations across multiple industries, with education being one of the most impacted areas [1], [2], [3], [4]. AI-driven Educational Technology (AI EdTech), which refers to the application of AI technologies in educational tools and platforms, promises to revolutionize traditional educational methods [5], [6]. Recent advancements in Large Language Models (LLMs)[1] and the emergence of generative AI[2] have significantly accelerated the development of AI EdTech [7], [8], [9]. In particular, there have been numerous instances of applying OpenAI[3] technologies, such as

[1]The LLM refer to advanced machine learning models designed to understand, generate, and manipulate human language. These models are typically trained on massive datasets containing diverse types of text.

[2]The Generative AI refers to a class of AI models designed to create new content, such as text, images, audio, and even video. These models learn from existing data and generate outputs that mimic or extend the data they were trained on.

[3]The OpenAI is a leading artificial intelligence research lab and organization dedicated to developing and promoting friendly AI for the benefit of all humanity.

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Generative Pre-trained Transformer (GPT), in educational settings. Specifically, Khan Academy has introduced an AI EdTech service called Khanmigo, which leverages OpenAI to enhance its educational offerings [10]. Also, ChatGPT Education (ChatGPT Edu) [11], which is a version of ChatGPT built for universities to responsibly deploy AI to students, faculty, researchers, and campus operations, was launched recently. Also, Google provides Learning Language Model (LearnLM) which is an AI language model fine-tuned for learning, and grounded in educational research to make teaching and learning experiences more active, personal and engaging [12]. In addition, copilot for Microsoft integrates AI capabilities for educators and students into everyday applications like Word, Excel, PowerPoint, and Teams [13].

Recent studies have highlighted the potential benefits of AI EdTech [14], [15], [16]. These include personalized learning experiences, improved accessibility, efficient administrative processes, and addressing teacher shortage [17], [18]. For instance, AI algorithms can analyze student data to tailor educational content to individual learning styles and paces [19], [20]. Therefore, AI EdTech is being applied in K-12[4] education in various innovative ways, aimed at enhancing personalized learning, supporting educators, and improving administrative efficiency. For example, digital textbooks for K-12 in South Korea are set to be officially implemented starting in 2025 in order to enhance both teaching and learning experiences [21]. Also, publishers such as Pearson [22] and McGraw-Hill [23] are striving to provide solutions for personalized learning for students through digital textbook-based data learning, not only for K-12 education but also for higher education. Furthermore, non-profit associations such as Educause [24] and 1EdTech [25] play a critical role in the education sector for effective digital learning environments. In addiiton, AI EdTech is also being actively adopted by many universities around the world. In particular, Arizona State University (ASU) has partnered with OpenAI to integrate advanced AI tools, including ChatGPT, into their educational programs which focus on enhancing student success, innovative research, and streamlining organizational processes [26].

On the other hand, there are also concerns about AI for unintended consequences, including ethical dilemmas, privacy breaches, and the amplification of biases [27]. Recently, current and former employees from leading AI companies have raised concerns about the risks associated with advanced AI technologies [28]. In the field of education as well, it also has not been verified yet for the effectiveness of AI Edtech [29], [30]. Also, there are many challenges to realizing AI Edtech for higher education. In higher education, where the size of universities varies and there is no standardized textbook for the majors and courses offered, the approaches to AI EdTech differ from one university to another. Moreover, AI technology is rapidly advancing day by day. Therefore, if the infrastructure for AI EdTech is established through such non-standardized approaches, there will be difficulties in continuously developing AI EdTech in the future.

Based on the aforementioned advantages and disadvantages of AI EdTech, this paper aims to suggest the direction that AI EdTech should take in higher education. Specifically, we provide a comprehensive look at the role of a professor and AI in the university. The key contributions are: i) We first identify the roles and core competencies of a professor (hereafter referred to as "human professor" which is differentiated with "AI professor") and then introduce examples of AI being applied in university education. ii) We provide a taxonomy with detailed definitions for five levels of AI professor, ranging from current status (Level 1) to full AI professor (Level 5), in the context of four AI companions including AI tutor, AI assistant, AI adviser, and AI professor. iii) We provide key capabilities and requirements according to the level evolution of the AI professor. Importantly, we present the educational and technical issues that AI EdTech faces when applied to higher education and propose future directions to these problems.

Given the importance of this topic, the paper is structured as follows: Section II examines the current state of university education, detailing the roles of traditional human professors and the recent incorporation of AI EdTech. Section III explores the various stages of AI professor development in universities, outlining the essential capabilities and requirements at each stage. Section IV addresses the challenges involved in realizing AI professors. Finally, Section V provides the conclusion.

II. EDUCATION IN THE UNIVERSITY

In this section, we present the job competencies of a human professor in five key aspects and provide examples of AI EdTech that support these competencies.

A. THE JOB COMPETENCIES OF A PROFESSOR

The role of a university professor is diverse and can vary significantly depending on their field of study [31]. For example, professors in the humanities and social sciences emphasize critical thinking, analysis, and interpretive skills. In contrast, those in Science, Technology, Engineering, and Mathematics (STEM) focus on experimental techniques and problem-solving. However, the job competencies of professors, as presented in Fig. 1, are generally applicable across all fields. A detailed explanation of each job competency is provided below:

1) **Expertise in the relevant field**: This is a fundamental requirement for professors. Specifically, professors should possess deep knowledge and skills in their subject areas to provide accurate and comprehensive education [32]. This expertise ensures that students receive high-quality instruction grounded in current research and practice. In contemporary educational settings, the role of professors encompasses a wide

[4]K-12 refers to the publicly-supported school grades prior to university or college in the United States and other countries.

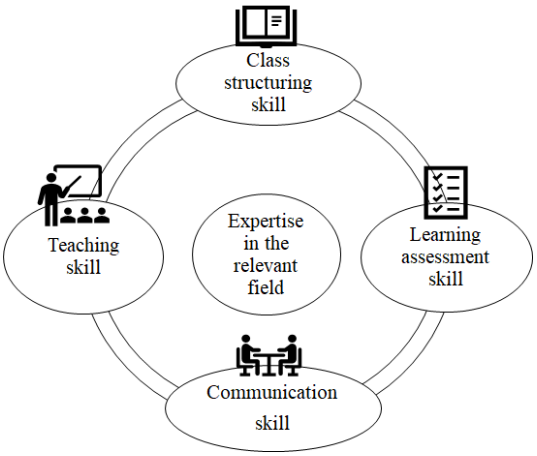

FIGURE 1. Job compentencies of a professor.

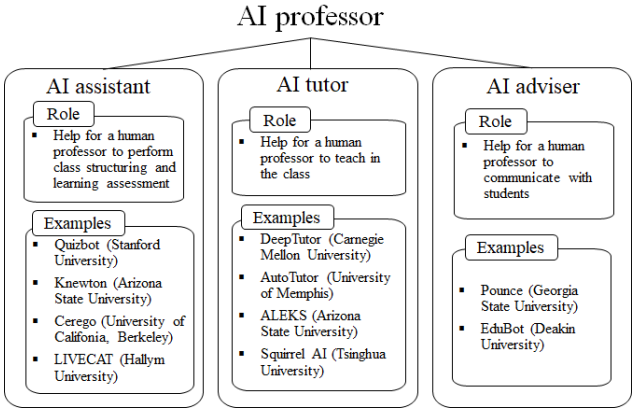

FIGURE 2. An examples of AI companions.

array of competencies that are crucial for effective teaching and learning.

2) **Class structuring skill**: Planning and preparing class materials is a core competency for professors [33]. Initially, professors should select a subject and then establish goals and a plan. The next step involves preparing the teaching materials. Analyzing students' backgrounds is crucial for delivering student-tailored education [34]. Essentially, the class should be prepared after understanding students' needs and prior knowledge. However, in traditional educational settings where one teacher instructs many students, it is challenging to prepare lessons tailored to the individual backgrounds of each student.
3) **Teaching skill**: Studies in [35], [36], and [37] consistently demonstrate that good teaching skills positively impact student learning and motivation. Effective teaching includes not only lectures but also discussions with students during class. Customized tutoring can be achieved through discussions and Q&A sessions. However, current typical teaching methods have limitations in providing customized tutoring to all students. Despite this, professors must employ diverse strategies tailored to various learning styles to maintain student engagement and facilitate deeper understanding.
4) **Learning assessment skill**: Learning assessment involves developing exams and assignments, monitoring students' progress, and ultimately grading. According to [38], students' academic achievements increase significantly when they receive constructive and continuous personalized feedback. However, in current typical assessment processes, it is practically difficult to evaluate students by reflecting their individual characteristics and providing personalized feedback. Effective assessment strategies will help students understand their progress and identify areas for improvement.
5) **Communication skill**: Professors need to communicate frequently with students to provide guidance about courses, careers, and research areas. According to [39], students regard professors' ability to communicate and interact effectively with them as the most essential competency. Effective communication fosters a supportive learning environment, enabling students to engage actively and feel valued. Professors should not only teach academic content but also contribute to shaping students' personalities and guiding them to become desirable members of society. This guidance helps students navigate their career paths and develop into well-rounded individuals [40], [41]. However, due to the busy schedules of professors, the time available for communication with students decreases, and it is easy to overlook the importance of this interaction.

There is no doubt that the five competencies described above are essential for professors in universities. However, as mentioned earlier, there are practical limitations to providing customized class structuring, teaching, learning assessment, and communication skills to students through traditional educational methods. Therefore, the next section will explore efforts to overcome these limitations by utilizing recent advancements in AI EdTech.

B. AI EDTECH

In the previous section, we explained the limitations of traditional teaching methods by human professors in providing personalized education. The positive effects of personalized education are already well known [42]. Consequently, many universities and educational institutions are considering AI EdTech as a solution to address these challenges [2], [5]. Specifically, many universities are implementing AI EdTech services such as AI assistants, AI tutors, and AI advisers, as illustrated in Fig. 2. From our understanding, AI assistants, AI tutors, and AI advisers can all be collectively referred to as AI professors, as their roles align with the competencies of human professors described in Section II-A. Therefore, in this paper, we define AI assistants, AI tutors, AI advisers, and AI professors collectively as AI companions which provide AI

EdTech services in the university. Below, we describe specific cases where these AI companions are applied.

Firstly, an AI assistant helps human professors with class structuring and learning assessment, as illustrated in Fig. 2. It is also beneficial for students by providing instant feedback on assignments and tests, allowing them to understand their mistakes and learn promptly. Automated grading systems for essays, quizzes, and coding assignments ensure that students receive timely and constructive feedback, enhancing their learning process [43]. The AI assistant facilitates access to a vast array of online resources and learning materials, aiding human professors in preparing lectures. It can help professors find relevant textbooks, research papers, and multimedia content tailored to their current classes and research interests [5]. Tools like Quizbot (Stanford University) [44] automatically generate quizzes for professors. Additionally, platforms such as Knewton (ASU) [45] and Cerego (University of Califonia, Berkeley) [46] assess student levels through grading and provide personalized learning materials. The LIVECAT platform [47] in the Hallym university evaluates the students' ability and latent traits based on computerized adaptive testing.

Secondly, an AI tutor assists human professors in teaching, as illustrated in Fig. 2. AI tutors can personalize instruction to meet individual students' needs, preferences, and learning paces. They tailor instructional materials, assignments, and assessments, ensuring each student engages with content at an appropriate difficulty level. This customization helps students understand complex concepts better and progress more effectively [42]. AI tools such as virtual reality (VR) and augmented reality (AR) provide immersive learning experiences, making complex subjects more engaging and easier to understand [48]. For instance, biology students can explore 3D models of the human body, while history students can experience historical events through VR simulations [49]. Advanced applications include L2TOR [50], where classes are conducted through Cobot [51], a robot capable of interacting with humans, and programs like DeepTutor (Carnegie Mellon University) [52] and AutoTutor (University of Memphis) [53], which uses natural language processing to deliver lectures, personalized assessments, and feedback without human intervention [43]. For example, Assessment and Learning in Knowledge Spaces (ALEKS) [54] is an adaptive learning platform used by ASU to help students in various subjects, particularly mathematics. Squirrel AI [55] at Tsinghua university continuously monitors student performance and adjusts the difficulty and focus areas in real-time to ensure optimal learning.

Thirdly, an AI advisor helps human professors communicate with students, as illustrated in Fig. 2. An AI advisor can provide guidance about courses, careers, and research areas. Additionally, AI advisors can streamline administrative tasks such as scheduling, enrollment, and resource allocation. Chatbots and virtual assistants can handle routine queries from students, allowing faculty and administrative staff to focus on more critical tasks, thus creating a smoother educational experience for students [5]. AI advisors can facilitate better collaboration among students through intelligent communication platforms that manage group projects, track contributions, and suggest optimal workflows. These tools help students work together more efficiently, fostering teamwork and project management skills [42]. AI advisor platforms such as Pounce (Georgia State University) [56], and EduBot (Deakin University) [57] support continuous learning beyond college by providing personalized recommendations for courses, reading materials, and skill development opportunities based on a student's evolving interests and career goals. This lifelong learning approach ensures that students remain competitive and adaptable in their professional lives.

Finally, AI assistants, AI tutors, and AI advisers can be integrated into an AI professor, as shown in Fig. 2. Alternatively, the term AI professor can be another name for these three AI companions, representing a key AI EdTech service in the future. To ensure that AI professors are meaningfully utilized in future university education, it is necessary to consider the current state of technological development and the future direction of evolution. Additionally, it is essential to identify the technical and educational elements required for this evolution. These aspects will be discussed further in the following section.

III. AI PROFESSOR

In this section, we discuss how AI EdTech is expected to evolve in the future, potentially taking over certain roles traditionally held by human professors in universities. Next, we outline the necessary capabilities and requirements for this development.

A. THE LEVELS OF AI PROFESSOR

Traditionally, human professors had handled all teaching tasks entirely without AI assistance. This traditional approach relies solely on the professor's competencies (See Section II-A) to deliver education. However, as we explained in Section II-B, AI EdTech is currently applied in many universities to provide a better education to students. At the end, the final goal of AI EdTech would be an AI professor which realizes full automation of human professors' role in the wide areas of fields and courses as much as possible. Inspired by the levels of automation in self-driving cars [58] and Aritificial General Intelligene (AGI) [59], we propose structuring the concept of AI professors similarly. At first, traditional teaching methods belong to Level 0 where human professors does not use AI assistance and utilize basic tools only such as authoring tools and traditional Learning Management Systems (LMS). With AI assistance, the evolution level of the AI professor can be categorized from Level 1 (Current status) to Level 5 (full automation) as shown in Fig. 3. Specifically, we explain about the taxonomy of five levels on AI professor as:

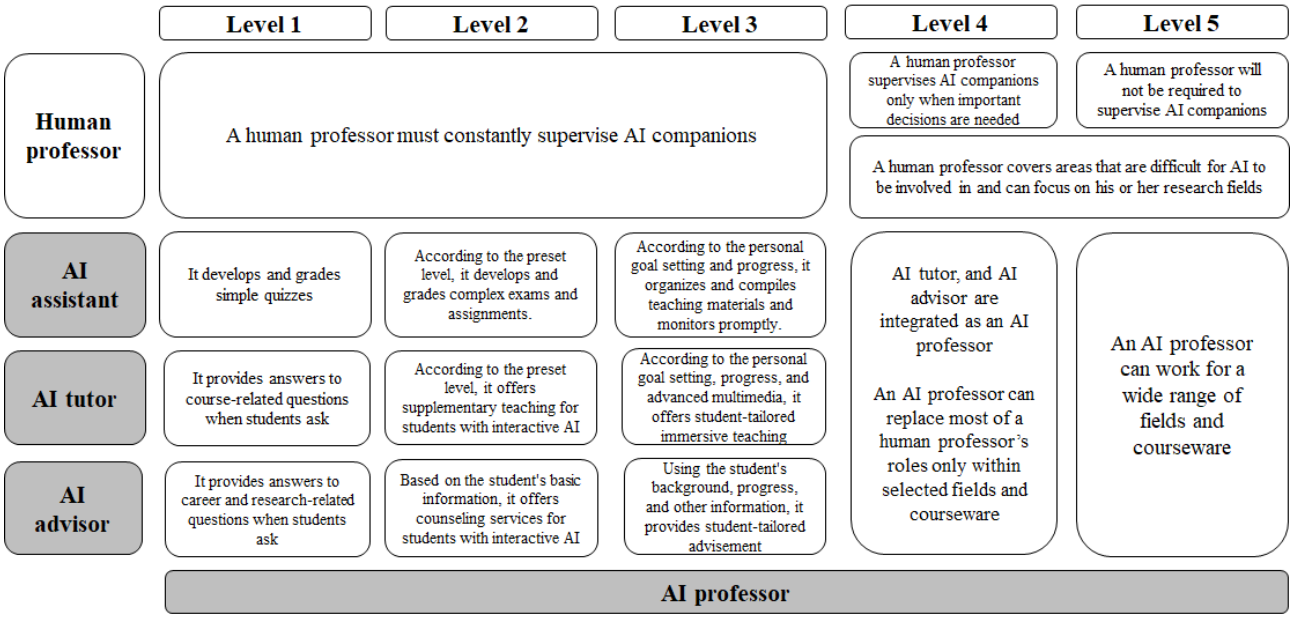

FIGURE 3. The evolution levels for an AI professor.

1) **Level 1 (Simple AI Assistance for Learning)**: Level 1 is the current status. At Level 1, the state-of-the-art AI in EdTech can offer basic functions of AI companions as illustrated in Fig. 3. However, at this level, AI EdTech does not provide satisfactory services on its own. Human professors should lead all teaching activities and maintain direct interaction with students to ensure effective learning.
2) **Level 2 (Preset Level-Based Customized Learning)**: At Level 2, AI EdTech offers customized AI companions which work based on pre-established levels. For example, levels can be divided into three categories: high, medium, and low. An AI tutor assesses the student's level, and based on this, the student can choose the desired level. Accordingly, the AI assistant creates and evaluates exam questions and assignments suitable for the chosen level. One important function at this level is the ability to interact closely with students, which significantly increases satisfaction.[5]
3) **Level 3 (Personal Goal Setting and Progress-Based Customized Learning)**: Level 3 offers personally customized AI companions. Unlike Level 2, Level 3 features customized learning based on individual goals and progress. Recognizing that each student has unique objectives, Level 3's AI companions begin by identifying these goals and then provide services specifically designed to achieve them according to the progress of learning. AI EdTech integrates extensive datasets, advanced analytics, and cutting-edge AI technologies to offer highly customized services as illustrated in Fig. 3. Additionally, advanced multimedia technologies such as AR, VR, and holograms provide immersive learning opportunities for students. However, human professors should still maintain their leadership roles, using the outputs from AI companions to inform their teaching decisions and monitor student progress.
4) **Level 4 (High Automation of AI Professor)**: Level 4 represents a high degree of automation in AI professor capabilities, allowing for minimal human management and supervision in selected fields and courses. At this stage, all AI companions can be integrated into a single AI professor, signifying that all functions of the AI companions are highly stabilized and seamlessly merged. However, human professors still need to supervise the AI companions when making important decisions and to address any malfunctions.
5) **Level 5 (Full Automation of AI Professor)**: At Level 5, full automation is achieved, and human professors will not be required to supervise AI companions. Compared to Level 4, AI professors at this stage can operate across a diverse array of fields and courseware.[6]

The emergence of AI professors does not signal the end of human professors. Human professors are still necessary to address areas where AI may struggle and to manage and supervise AI companions [62], ensuring their accuracy and safety–a topic discussed in the next subsection.

[5]Interaction and communication between professors and students are crucial for effective learning, as indicated by studies in [33], [39], [60], and [61]. The AI adviser and AI tutor can be helpful in this aspect even though AI may struggle to fully understand the learners' status.

[6]The courseware refers to any digital content designed to be used in an educational course.

Additionally, human intervention in AI EdTech is crucial to mitigate potential side effects, as explored in Section IV-A. Therefore, the collaboration between human and AI professors could foster a more advanced higher education environment in the future.

B. KEY CAPABILITIES AND REQUIREMENTS

As explained in the previous section, the ultimate goal of AI EdTech in the university is to develop an AI professor, which integrates the roles of AI assistant, AI tutor, and AI adviser, collectively known as AI companions. The evolution of these AI companions relies on the following key capabilities:

- **AI accuracy**: The proportion of correct predictions made by AI companions out of the total number of predictions.
- **AI safety**: The evaluation of technical, ethical, and operational aspects to ensure that the responses of AI companions are reliable, trustworthy, and aligned with human values.
- **Hardware performance**: The performance evaluated by the combined capabilities of hardware components, including Graphics Processing Units (GPUs), Tensor Processing Units (TPUs), custom AI chip, cloud infrastructure, edge computing devices, and high-resolution and accurate displays.
- **Software performance**: The performance is evaluated based on the combined capabilities of software components, including the Natural Language Processing (NLP) technologies, adaptive learning algorithms, multimedia software for AR and VR, and high-speed, low-latency networks.
- **Professor satisfaction**: The evaluation of human professors' satisfaction after integrating AI companions into their teaching.
- **Student satisfaction**: The evaluation of students' satisfaction after using AI companions in their learning.
- **Sustainability**: Evaluating the extent of support for lifelong education through continuous updates and expansions of AI EdTech and resources
- **Interoperability**: Evaluating the seamless integration of AI EdTech solutions with existing systems and future technologies
- **The amount of courseware**: The number of coursewares aiming to enhance the AI EdTech experience for teaching and learning.

As the AI professor advances to higher levels, it is expected to offer significantly enhanced capabilities compared to the lower levels. The capabilities of the AI professor and its Key Performance Indicators (KPIs) are illustrated in Fig. 4, which compares the KPIs as the AI professor's level increases. The values in Fig. 4 serve as targets for research and investigation and may be revised based on future studies. The specific targets and corresponding requirements are detailed below.

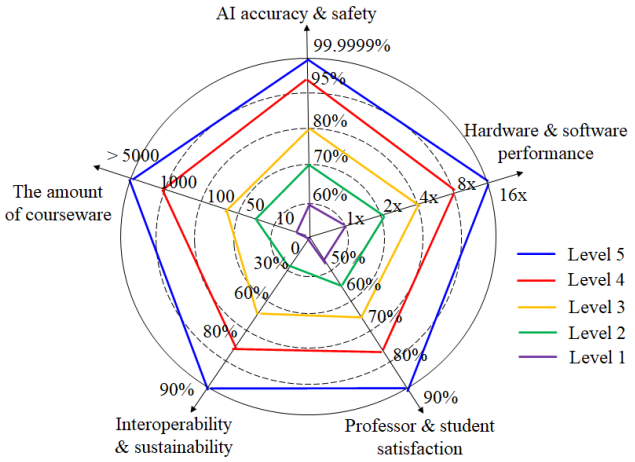

FIGURE 4. Key capabilitis and corresponding requirements for an AI professor.

The Level 1 (i.e., current level) of AI accuracy and safety for the task of AI companions is not expected to reach more than 60% due to the lack of data sets on higher education. However, the goal is to achieve an accuracy and safety rate of 99.9999% at Level 5, eliminating the need for human professors to supervise AI companions. To enhance AI accuracy, it is crucial to acquire extensive datasets that include teaching materials, students' backgrounds and progress, job market and graduates' information, research trends, and more. Additionally, fine-tuning LLMs can optimize pre-trained model parameters by adjusting them to specific datasets for AI EdTech purposes. Customizing general-purpose LLMs for specific purposes is essential [63], employing techniques such as Parameter-Efficient Fine-Tuning (PEFT) [64] and Retrieval-Augmented Generation (RAG) [65]. AI EdTech systems must be trained, controlled, and managed to ensure they provide safe responses to students. Here, 'safety' is a broad concept that includes reliability, controllability, alignment with human values, bias mitigation within datasets, and governance [66], [67]. Therefore, developing enhancement technologies for AI accuracy and safety involves Human-In-The-Loop (HITL) approaches (utilizing expert feedback and domain knowledge) [68] and selective prediction [69].

The convergence of advanced hardware and sophisticated software in AI EdTech is revolutionizing the education sector. Significant strides have been made in AI hardware technology, yet continued development is essential to address current limitations in computational efficiency [70], scalability [71], and energy consumption [72]. In terms of AI software, OpenAI has recently established a set of five levels to track its progress, with the current status estimated at Level 1, which supports chatbots [73]. Additionally, ultimate multimedia services via AR, VR, and high-fidelity holograms are crucial for immersive educational experiences. However, these services face critical obstacles due to both hardware and software limitations [74]. In particular, hardware evolution is needed for advanced device form-factors, such as handheld components, to support mobile and active software content.

Current mobile devices lack sufficient stand-alone computing capability. Unfortunately, progress in hardware performance, especially mobile computing power and battery capacity, cannot keep pace with the demands of ultimate multimedia services with AI EdTech. This discrepancy could severely hinder market expansion. We believe these hardware challenges can be overcome by offloading computing to more powerful devices or servers. For instance, the scalability of cloud solutions combined with powerful edge devices ensures that ultimate multimedia services are accessible across various educational settings, from urban schools to remote learning environments. On the software front, another challenge is sufficient wireless capacity. Current AR technology requires 55.3 megabits per second (Mbps) to support an 8K display (with one million points), which provides an adequate user experience on a mobile display. However, to provide a truly immersive AR experience, the density must be significantly improved, requiring 0.44 gigabits per second (Gbps) throughput (with 16 million points). Additionally, a human-sized hologram demands a significantly large number of pixels, requiring several terabits per second (Tbps) [75]. The current user-experienced data rate of 5G is insufficient to support these services. Therefore, both hardware and software technologies must be further developed to realize personalized learning, real-time feedback, and immersive educational experiences, enhancing both teaching and learning outcomes, as depicted in Fig. 4.

In higher education, the purpose of AI Edtech is to provide high satisfaction for both professors and students by integrating AI companions into teaching and learning. As explained in Fig. 4, the current Level 1 of AI EdTech only offers simple services, with an anticipated satisfaction rate not exceeding 50%. Many universities view AI EdTech as a significant driver of academic innovation, leading to the implementation of AI companions, as detailed in Section II-B. The primary goal of AI EdTech is to evolve in a way that enhances the satisfaction of both professors and students. To increase professors' satisfaction, AI EdTech should significantly reduce their workload, allowing them to focus more on research and devote more attention to students. For students, personalized education through AI EdTech must be prioritized to enhance their satisfaction. Additionally, diverse learning experiences should be provided through advancements in AI and multimedia technologies. These improvements in education quality can lead to increased student satisfaction and a reduction in dropout rates. As illustrated in Fig. 4, achieving a 90% satisfaction rate for both professors and students at Level 5 demonstrates the educational effectiveness of AI EdTech.

At present, AI companions at Level 1 are not being developed with considerations for sustainability and interoperability. However, as AI EdTech continues to evolve and seeks widespread adoption in many universities, these two factors become crucial. The optimal approach to achieving sustainability and interoperability is through the standardization of AI EdTech. When stakeholders involved in developing and implementing AI EdTech collaborate to standardize it, AI EdTech is expected to successfully integrate into university systems. Consequently, at Level 5, the achievement rate for sustainability and interoperability should exceed 90%, as depicted in Fig. 4.

Assuming undergraduate students take roughly 40 courses and there are 100 majors in a four-year university, the total number of courses would be 4,000. In higher education, which emphasizes autonomy, the same course can be taught in diverse ways depending on the professor's competency and judgment. This diversity presents challenges in developing courseware for higher education, as there can be multiple courseware options for each course. Currently, courseware development is focused on specific subjects that are conducive to applying AI EdTech at Level 1. For example, it is limited to subjects like coding in computer science, mathematics, and chemistry [76]. However, as AI EdTech evolves to higher levels, there will be a need for courseware to be applied across a broader range of fields. The number of supported courseware offerings should also increase, as shown in Fig. 4. To achieve this, efforts are required to gather data on various subjects and develop courseware accordingly. This involves creating a comprehensive database of educational content and leveraging AI to generate diverse and effective courseware that can cater to the wide range of subjects offered in universities.

IV. MAJOR CHALLENGES FOR MAKING AI PROFESSOR A REALITY

Despite the potential benefits of the AI professor, educational and technical issues remain for its successful integration into higher education. This paper raises two questions to discuss the potential issues and to suggest future directions of the AI professor.

A. IS AI PROFESSOR EDUCATIONALLY EFFECTIVE?

To ensure the successful integration and widespread utilization of AI professors in universities, the educational effectiveness of AI professors should be clearly validated. However, there is currently limited evidence on the large-scale adoption and effectiveness of AI professors in an educational context [77], and there are concerns about the following:

- **Restriction for self-regulated learning**
- **Loss of human interaction**
- **Exacerbating educational inequities**

First, a highly developed AI professor may limit opportunities and affordances for self-regulated learning for some students [78]. Self-regulated learning refers to the process by which students personally activate and maintain cognitions and behaviors systematically directed toward achieving academic learning goals [79]. According to the theory of self-regulated learning, learners evaluate the effectiveness of their own learning methods or strategies during the learning

process and make appropriate adjustments through internal changes or behavior modification [79]. The personalized learning approach driven by AI professors is based on individual preferences and activity data. From the perspective of behaviorism, AI can be seen as a tool that restricts learners' opportunities to explore and evaluate diverse strategies and methodologies within the learning process. AI analyzes learners' behavioral patterns, suggests learning plans, and provides feedback based on a set algorithm. This makes learners more likely to adhere to the rules set by the system and follow the learning path suggested by the AI rather than explore new ways to learn. In other words, a student assisted by an AI professor may experience customized learning while simultaneously decreasing their ability to set, explore, and evaluate their own goals. Additionally, generative AI still has the potential to create misleading or misinformative content or provide too much or too little feedback. If learners rely too heavily on the technology, they may encounter inaccurate learning resources or receive inconsistent or inappropriate feedback based solely on information generated by AI, rather than exploring and evaluating learning resources themselves to modify their behavior. This can limit self-regulated learning and reduce the quality of learning [80].

Another concern regarding AI professors is the potential reduction in human interaction between students and human professors. While AI professors can efficiently deliver personalized content, they cannot replicate the empathy, mentorship, and nuanced understanding that human professors provide. This loss of human interaction can lead to a less engaging and supportive learning environment, which is particularly detrimental during the university years, a critical period for emotional and social development [81]. The emotion learners experience during the learning process affects not only their psychological stability but also their learning satisfaction, academic performance, and more [82]. If AI professors can understand and respond to learners' emotions, they can increase learner participation and reduce dropouts. Positive effects can be expected in terms of providing customized feedback, enhancing learning motivation, and offering psychological support.

In addition, a concern with AI professors is the issue of educational inequality. This is known as the Matthew effect [83], which suggests that learners who benefit the most from the use of new technologies are those who already possess wealth, existing levels of education, and familiarity with technology. This means that new resources, even free online resources, will be utilized most effectively by learners who already have access to technology and know how to use it [84]. This phenomenon has become even more pronounced during the COVID-19 pandemic, as schools around the world transitioned to remote learning [85]. Students with access to computers and the Internet were able to quickly adapt to remote learning and had easier access to online learning platforms [86]. Conversely, students with limited access to technology not only had restricted access to their classes but also had to spend more time setting up digital learning environments, which detracted from their actual learning time [87], [88]. Despite efforts to bridge the gap between students and achieve equitable education, public education has shown a tendency to exacerbate this gap through the adoption of technology. Without understanding this phenomenon, AI professors have the potential to worsen existing disparities in the education system.

Based on the aforementioned issues, we provide future directions for AI professors in the educational aspect as follows:

- **Intentional and collaborative design of AI professor**
- **Verification on the effectiveness of AI professor**
- **Involvement of human professor**

First, for AI professors to facilitate effective learning in online, hybrid, and in-person environments, intentional design is required [89], [90]. Specifically, the AI professor should be designed to promote self-regulated learning. This can be achieved through appropriate fine-tuning when AI is applied to education, as discussed in Section III-B. Furthermore, AI professors should be designed intentionally in ways that enhance students' creativity [91]. Also, it is essential that designs accommodate the diverse characteristics of students, including gender, abilities, learning styles, language, and ethnicity. Enhancing the accessibility of AI professors is a prerequisite for minimizing educational disparities among students and fostering a healthy AI EdTech ecosystem. The principles of Universal Design for Learning (UDL) can be applied to this end. UDL, as provided by CAST [92], offers an intentional and systematic framework for considering the diversity of learners with respect to multiple representations, behaviors and expressions, and learning engagement. By incorporating these considerations into the design of AI professors, barriers created by factors such as gender, age, and disability can be broken down, actively supporting students in achieving their learning goals. Furthermore, collaborative design, involving human professors, students, technicians, and policymakers in the university, should be a key focus [6], [93]. By integrating knowledge and visions of AI EdTech developers with the actual needs of users, we can develop AI professors that are accessible, adaptable, and capable of addressing real-world challenges.

Secondly, the effectiveness of AI professors should be rigorously evaluated and monitored. In other words, it is necessary to verify their impact using scientific procedures and methods, which requires further research and development. As previously mentioned, there is a lack of definitive validation regarding the influence of AI professors in actual educational settings [94]. Therefore, it is essential to analyze how AI professors affect both human professors and students. Investigating the experiences of human professors using AI professors and demonstrating the impact on students through rigorous scientific inquiry is crucial. Additionally, efforts should be made to address and mitigate any adverse events through evidence-based research.

Lastly, human professors should play a key role in effectively integrating AI professors into the classroom. While the advancement of AI professors aims to automate some roles of human professors, this does not negate the need for human intervention, as discussed in Section III-A. To ensure that the educational process within an AI-integrated classroom truly constitutes learning, it is imperative that the human professor assumes a leadership role in the entire learning activity [95]. This includes considering the roles, limitations, and ethical aspects of AI professors, emphasizing the orchestrator role of the human professor [96]. In [97], the Intelligent Technological Pedagogical and Content Knowledge (TPACK) framework was introduced, focusing on educators' ability to ethically and proficiently incorporate AI into their teaching practices [29], [98]. This study underscores the significance of TPACK competencies in equipping educators with the necessary knowledge and pedagogical skills to seamlessly integrate technology into their instructional methods. Actually, various data in higher education, such as students' learning records, grades, behavioral patterns, career paths, and employment, can be collected and utilized in AI, leading to ethical issues related to safety and privacy [99]. Therefore, even with the advent of Level 5 AI professors, human professors need to be involved in AI EdTech to address any issues and fill the gaps that AI cannot support. While AI can provide valuable support and efficiency, the unique competencies of human professors remain indispensable in fostering holistic student development.

B. IS AI PROFESSOR TECHNICALLY FEASIBLE?

As discussed in Section III-A, the AI professor represents the ultimate vision of AI companions that AI Edtech aims to achieve in higher education. However, whether the AI professor can continuously evolve to perform its expected roles adequately is contingent upon addressing the following technical issues as:

- **AI professor stability for data utilization**
- **Feasibility of AI professor for reliable recognition technology and ultimate multimedia experiences**
- **Scalability and flexibility of AI Edtech**

First and foremost, the realization of an AI professor heavily depends on educational data. Specifically, this includes class-related materials provided by human professors as well as data related to students' information. These data should be processed and learned by AI technologies to produce desirable outcomes in higher education. This implies that AI technology should reliably ensure AI accuracy and AI safety as discussed in Section III-B. Without guaranteed stability of AI technology, achieving a Level 5 AI professor would be challenging.

In addition, the AI professor should be able to recognize the state of students and provide appropriate feedback, akin to a human professor. With AI professors, students will have a flexible learning environment where they can learn at their own pace, free from the limitations of time and place. An essential technology for this will be a monitoring system that assesses student attention using a variety of methods to increase engagement. Researchers have attempted to assess students' concentration and emotional states by analyzing their eye movements. Various types of eye-tracking devices, such as tower-mounted eye trackers, screen-based eye trackers, head-mounted/wearable eye trackers, and mobile eye trackers, have been developed for this purpose [100]. Recent advances in technology have made it possible to monitor students' concentration levels through changes in pupil dilation or to analyze eye movement patterns to classify students and provide feedback without the need for additional external equipment [101], [102]. However, the diversity of learners' backgrounds (e.g., cultural, social, economic, situational factors) makes it difficult to interpret the context or nuances of learners' statuses. For example, if the artificial intelligence system has limited awareness of various background factors, such as accent, dialect, and cultural differences, it may inaccurately assess the learner's progress or create inconsistencies in understanding feedback expectations [103]. These factors can impact the effectiveness of educational services supported by AI professors. Therefore, cognitive technologies should be advanced to provide high reliability in recognizing students' states. Additionally, the AI professor should offer more advanced multimedia experiences to enhance the learning environment and educational outcomes. For instance, if services such as AR, VR, and holograms, as discussed in Section III-B, are realized, a ubiquitous educational environment can be provided, enabling immersive learning experiences. However, current technology faces limitations in delivering these ultimate multimedia experiences.

Moreover, AI EdTech platforms should be designed to handle increasing volumes of data and user interactions without compromising performance [104]. This requires scalable architecture, efficient database management systems, and robust server infrastructure. Flexibility refers to the ease with which AI systems can be updated or reconfigured to incorporate new features, educational content, or pedagogical approaches. Ensuring that AI EdTech platforms are built on modular and interoperable frameworks can enhance their scalability and flexibility.

Based on the aforementioned issues, we here provide future directions of the AI professor in the technical aspect as:

- **Development of an education-specialized LLM for ensuring AI accuracy and safety**
- **Hardware and software technology enhancements afforded by advances in communication, sensing, imaging, displaying and AI**
- **Standardization of AI EdTech platform and service**

To ensure the stability of the AI professor, as suggested in Section III-B, the performance of AI accuracy and AI safety must be developed to reach Level 5. This necessitates the development of LLMs specialized in higher education.

Compared to K-12 education, higher education encompasses numerous majors and courses, and textbooks are not standardized, making the development of a universally applicable LLM for all higher education a challenging task. Consequently, an approach of fine-tuning LLMs by specific major or course may be advantageous. To this end, a HITL [68] approach, wherein human professors in each field adjust and verify the LLMs, will be required. Furthermore, research and development of algorithms for fine-tuning LLMs for AI Edtech is important.

Next, it is a reality that there are significant technical limitations in enabling the AI professor to reliably recognize the state of students and provide ultimate multimedia experiences in the educational process. For instance, if a student deliberately engages in behaviors to evade recognition technologies, there will be technical limitations in accurately detecting such actions. As mentioned in Section III-B, there may be constraints in supporting high communication speeds necessary for realizing holograms. To overcome these limitations, solutions must be provided through the integration and complementary use of various technological fields. For example, it is crucial to integrate advanced technologies such as communication, sensing, imaging, display, and AI to deliver enhanced hardware and software performance.

Finally, standardization is the most effective alternative to design the AI EdTech platform with scalability and flexibility. If the platform and the service such as AI professors are developed independently by each university without standardization, maintenance and updates for these platforms and services could become challenging. This is due to the significant costs and resources required to build and sustain such AI EdTech platforms and services. By pursuing the standardization of AI EdTech with scalability and flexibility, and continuously enhancing these standardized platforms and services, AI EdTech can be successfully implemented in many universities worldwide.

V. CONCLUSION

This paper explored the significant roles of professors within universities and the potential of integrating AI into educational practices. Through a thorough investigation, we identified and exemplified the essential roles of professors and demonstrated how these roles can be augmented with AI EdTech in university settings. We introduced a developmental framework for AI professors, categorizing their advancement from levels 1 to 5, and detailed the technological progressions and educational components required at each stage. Furthermore, we specified the capabilities and prerequisites for each development level. We also examined the educational and technical challenges associated with implementing AI professors, proposing strategies to address these obstacles. Moving forward, our research will focus on identifying the crucial functionalities and technological advancements needed to design AI EdTech platforms that align with the AI professor development framework. Additionally, we aim to outline a path for standardizing these AI-driven educational tools to ensure widespread adoption and efficacy.

REFERENCES

[1] S. A. D. Popenici and S. Kerr, "Exploring the impact of artificial intelligence on teaching and learning in higher education," *Res. Pract. Technol. Enhanced Learn.*, vol. 12, no. 1, p. 22, Nov. 2017, doi: 10.1186/s41039-017-0062-8.

[2] L. Chen, P. Chen, and Z. Lin, "Artificial intelligence in education: A review," *IEEE Access*, vol. 8, pp. 75264–75278, 2020, doi: 10.1109/ACCESS.2020.2988510.

[3] F. Almasri, "Exploring the impact of artificial intelligence in teaching and learning of science: A systematic review of empirical research," *Res. Sci. Educ.*, Jun. 2024, doi: 10.1007/s11165-024-10176-3.

[4] H. Crompton and D. Burke, "Artificial intelligence in higher education: The state of the field," *Int. J. Educ. Technol. Higher Educ.*, vol. 20, no. 1, p. 22, Apr. 2023, doi: 10.1186/s41239-023-00392-8.

[5] F. Pedró, M. Subosa, A. Rivas and P. Valverde. (2019). *Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development*. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000366994?posInSet=1=2c58492c-931f-47d2-967d-7194427f4062

[6] M. A. Chaudhry and E. Kazim, "Artificial intelligence in education (AIEd): A high-level academic and industry note 2021," *AI Ethics*, vol. 2, no. 1, pp. 157–165, Feb. 2022, doi: 10.1007/s43681-021-00074-z.

[7] B. Baker, K. A. Mills, P. McDonald, and L. Wang, "AI, concepts of intelligence, and chatbots: The 'figure of man,' the rise of emotion, and future visions of education," *Teachers College Rec., Voice Scholarship Educ.*, vol. 125, no. 6, pp. 60–84, Jun. 2023, doi: 10.1177/01614681231191291.

[8] A. Olga, Tzirides, A. Saini, G. Zapata, D. Searsmith, B. Cope, M. Kalantzis, V. Castro, T. Kourkoulou, J. Jones, R. A. da Silva, J. Whiting, and N. P. Kastania, "Generative AI: Implications and applications for education," 2023, *arXiv:2305.07605*.

[9] J. Mao, B. Chen, and J. C. Liu, "Generative artificial intelligence in education and its implications for assessment," *TechTrends*, vol. 68, no. 1, pp. 58–66, Jan. 2024, doi: 10.1007/s11528-023-00911-4.

[10] W. A. Sahlman, A. M. Ciechanover, and E. Grandjean, "Khanmigo: Revolutionizing learning with GenAI," Harvard Bus. School, Boston, MA, USA, Tech. Rep. 824-059, Nov. 2023.

[11] Y. Albadarin, M. Saqr, N. Pope, and M. Tukiainen, "A systematic literature review of empirical research on ChatGPT in education," *Discover Educ.*, vol. 3, no. 1, p. 60, May 2024, doi: 10.1007/s44217-024-00138-2.

[12] J. Kemper. *Google Unveils LearnLM, Bringing Generative AI to the Classroom*. Decoder. Accessed: Jul. 1, 2024. [Online]. Available: https://the-decoder.com/google-unveils-learnlm-bringing-generative-ai-to-the-classroom/

[13] A. J. Adetayo, M. O. Aborisade, and B. A. Sanni, "Microsoft copilot and anthropic Claude AI in education and library service," *Library Hi Tech News*, Jan. 2024, doi: 10.1108/lhtn-01-2024-0002.

[14] K. Zhang and A. B. Aslan, "AI technologies for education: Recent research & future directions," *Comput. Educ. Artif. Intell.*, vol. 2, Jan. 2021, Art. no. 100025, doi: 10.1016/j.caeai.2021.100025.

[15] B. I. Edwards and A. D. Cheok, "Why not robot teachers: Artificial intelligence for addressing teacher shortage," *Appl. Artif. Intell.*, vol. 32, no. 4, pp. 345–360, Apr. 2018, doi: 10.1080/08839514.2018.1464286.

[16] O. Hamal, N.-E. El Faddouli, M. H. A. Harouni, and J. Lu, "Artificial intelligent in education," *Sustainability*, vol. 14, no. 5, p. 2862, Mar. 2022, doi: 10.3390/su14052862.

[17] S. Triberti, R. Di Fuccio, C. Scuotto, E. Marsico, and P. Limone, "'Better than my professor?' How to develop artificial intelligence tools for higher education," *Frontiers Artif. Intell.*, vol. 7, Apr. 2024, Art. no. 1329605, doi: 10.3389/frai.2024.1329605.

[18] O. Tapalova and N. Zhiyenbayeva, "Artificial intelligence in education: AIEd for personalised learning pathways," *Electron. J. e-Learning*, vol. 20, no. 5, pp. 639–653, Dec. 2022, doi: 10.34190/ejel.20.5.2597.

[19] B. Pardamean, T. Suparyanto, T. W. Cenggoro, D. Sudigyo, and A. Anugrahana, "AI-based learning style prediction in online learning for primary education," *IEEE Access*, vol. 10, pp. 35725–35735, 2022, doi: 10.1109/ACCESS.2022.3160177.

[20] United Nations Educ. Scientific Cultural Org. (UNESCO). *How Can Artificial Intelligence Enhance Education?*. Accessed: Jul. 19, 2024. [Online]. Available: https://www.unesco.org/en/articles/how-can-artificial-intelligence-enhance-education

[21] Korea Ministry Educ. *Innovate Education With EdTech*. Accessed: Jul. 19, 2024. [Online]. Available: https://www.moe.go.kr/boardCnts/viewRenew.do?boardID=72769&lev=0&statusYN=W&s=moe&m=0315&opType=N&boardSeq=96531

[22] J. Fan, Y. Jin, X. Kong, and X. Zhang. (May 2021). *How do Test Takers Prepare for Computerized Speaking Tests? A Comparative Study of the PTE Academic and the CET-SET*. Language Testing Research Centre, Univ. Melbourne. Accessed: Jul. 20, 2024. [Online]. Available: https://pearsonpte.com/ctf-assets/yqwtwibiobs4/3yvIacPaxrMkeCwWVAxpur/8ef6ae8db24c03da682236499c6bbe91/

[23] J.-C. Falmagne, D. Albert, C. Doble, D. Eppstein, and X. Hu, *Knowledge Spaces: Applications in Education*. Berlin, Germany: Springer, 2013.

[24] D. G. Oblinger, *Game Changers: Education and Information Technologies*. Washington, DC, USA: Educause, 2012.

[25] J. Fritz. (Mar. 5, 2024). *Coalition of Education and Edtech Leaders Releases Framework for Trusted Digital Credentials*. Accessed: Jul. 20,2024. [Online]. Available: https://www.1edtech.org/1edtech-article/coalition-of-education-and-edtech-leaders-releases-framework-for-trusted-digital

[26] P. Mishra, M. Warr, and R. Islam, "TPACK in the age of ChatGPT and generative AI," *J. Digit. Learn. Teacher Educ.*, vol. 39, no. 4, pp. 235–251, Aug. 2023, doi: 10.1080/21532974.2023.2247480.

[27] M. Bond, H. Khosravi, M. De Laat, N. Bergdahl, V. Negrea, E. Oxley, P. Pham, S. W. Chong, and G. Siemens, "A meta systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour," *Int. J. Educ. Technol. High. Educ.*, vol. 21, no. 4, p. 4, Jan. 2024, doi: 10.1186/s41239-023-00436-z.

[28] *A Right to Warn About Advanced Artificial Intelligence*. Accessed: Jul. 18, 2024. [Online]. Available: https://righttowarn.ai/

[29] O. Zawacki-Richter, V. I. Marín, M. Bond, and F. Gouverneur, "Systematic review of research on artificial intelligence applications in higher education—Where are the educators?" *Int. J. Educ. Technol. Higher Educ.*, vol. 16, no. 1, p. 39, Oct. 2019, doi: 10.1186/s41239-019-0171-0.

[30] T. K. F. Chiu, "A classification tool to foster self-regulated learning with generative artificial intelligence by applying self-determination theory: A case of ChatGPT," *Educ. Technol. Res. Develop.*, Apr. 2024, doi: 10.1007/s11423-024-10366-w.

[31] S. Shankar, N. Gowtham, and T. P. Surekha, "Faculty competency framework: Towards a better learning profession," *Proc. Comput. Sci.*, vol. 172, pp. 357–363, Jun. 2020, doi: 10.1016/j.procs.2020.05.055.

[32] M. F. Carrillo, S. S. Henríquez, and E. F. Manzi, "Concepciones de los estudiantes para profesor de Matemáticas sobre las competencias profesionales implicadas en la enseñanza de la Estadística," *Rev. Electron. Investig. Educ.*, vol. 13, no. 2, pp. 113–131, Jul. 2011.

[33] K. S. Smith and R. D. Simpson, "Validating teaching competencies for faculty members in higher education: A national study using the Delphi method," *Innov. Higher Educ.*, vol. 19, no. 3, pp. 223–234, Mar. 1995, doi: 10.1007/bf01191221.

[34] W. Dick, L. Carey, and J. O. Carey, *The Systematic Design of Instruction*, 8th ed., Boston, MA, USA: Pearson, 2015.

[35] A. Parpala, S. Lindblom-Ylänne, and H. Rytkönen, "Students' conceptions of good teaching in three different disciplines," *Assessment Eval. Higher Educ.*, vol. 36, no. 5, pp. 549–563, Aug. 2011, doi: 10.1080/02602930903541023.

[36] P. Ramsden, *Learning to Teach in Higher Education*, 2nd ed., Evanston, IL, USA: Routledge, 2003.

[37] J. D. Vermunt, "The power of teaching-learning environments to influence student learning," *Brit. J. Educ. Psychol. Monogr. Ser. II*, vol. 4, pp. 73–90, Jan. 2007.

[38] D. Glenn, F. Patel, S. Kutieleh, J. Robbins, H. Smigiel, and A. Wilson, "Perceptions of optimal conditions for teaching and learning: A case study from flinders university," *Higher Educ. Res. Develop.*, vol. 31, no. 2, pp. 201–215, Apr. 2012, doi: 10.1080/07294360.2011.555390.

[39] A. C. Martínez, "?'Cómo es el buen profesor universitario según el alumnado?" *Revista Española de Pedagogía*, vol. 68, no. 246, pp. 223–242, Nov. 2023, doi: 10.22550/2174-0909.2471.

[40] A. V. Mahulae, P. Lumbanraja, and E. Siahaan, "Effect of professionalism and competence of teachers on teacher performance and its impact on student learning outcomes at Harapan Mandiri college," *Int. J. Res. Rev.*, vol. 7, no. 11, pp. 38–46, Nov. 2020.

[41] G. Cebrián, M. Junyent, and I. Mulà, "Competencies in education for sustainable development: Emerging teaching and research developments," *Sustainability*, vol. 12, no. 2, p. 579, Jan. 2020, doi: 10.3390/su12020579.

[42] W.-H. Kim and J.-H. Kim, "Individualized AI tutor based on developmental learning networks," *IEEE Access*, vol. 8, pp. 27927–27937, 2020, doi: 10.1109/ACCESS.2020.2972167.

[43] V. Rus, S. D'Mello, X. Hu, and A. C. Graesser, "Recent advances in conversational intelligent tutoring systems," *AI Mag.*, vol. 34, no. 3, pp. 42–54, Sep. 2013, doi: 10.1609/aimag.v34i3.2485.

[44] S. Ruan, L. Jiang, J. Xu, B. J.-K. Tham, Z. Qiu, Y. Zhu, E. L. Murnane, E. Brunskill, and J. A. Landay, "QuizBot: A dialogue-based adaptive learning system for factual knowledge," in *Proc. CHI Conf. Human Factors Comput. Syst.*, May 2019, pp. 1–13, doi: 10.1145/3290605.3300587.

[45] T. A. Conklin, "Knewton (An adaptive learning platform available at https://www.knewton.com/)," *Acad. Manage. Learn. Educ.*, vol. 15, no. 3, pp. 635–639, Sep. 2016, doi: 10.5465/amle.2016.0206.

[46] B. Homer and J. Plass, "Innovating randomized effectiveness trials: The case of an adaptive learning engine for e-learning in high schools," in *Proc. E-Learn, World Conf. E-Learn. Corporate, Government, Healthcare, Higher Educ.*, Kona, HI, USA, 2015, pp. 1105–1114.

[47] D. G. Seo and J. Choi, "Introduction to the LIVECAT web-based computerized adaptive testing platform," *J. Educ. Eval. Health Professions*, vol. 17, p. 27, Sep. 2020, doi: 10.3352/jeehp.2020.17.27.

[48] M. Wang and M. Kang, "Cybergogy for engaged learning: A framework for creating learner engagement through information and communication technology," in *Engaged Learning With Emerging Technologies*. Dordrecht, The Netherlands: Springer, 2006, pp. 225–253.

[49] T. A. Mikropoulos and A. Natsis, "Educational virtual environments: A ten-year review of empirical research (1999–2009)," *Comput. Educ.*, vol. 56, no. 3, pp. 769–780, Apr. 2011, doi: 10.1016/j.compedu.2010.10.020.

[50] T. Belpaeme, J. Kennedy, P. Baxter, P. Vogt, E. E. J. Krahmer, S. Kopp, K. Bergmann, P. Leseman, A. C. Küntay, T. Göksun, A. K. Pandey, R. Gelin, P. Koudelkova, and T. Deblieck, "L2TOR—Second language tutoring using social robots," in *Proc. ICSR Wonder Workshop*, Paris, France, 2015, pp. 1–6.

[51] S. El Zaatari, M. Marei, W. Li, and Z. Usman, "Cobot programming for collaborative industrial tasks: An overview," *Robot. Auto. Syst.*, vol. 116, pp. 162–180, Jun. 2019, doi: 10.1016/j.robot.2019.03.003.

[52] V. Rus, N. Niraula, and R. Banjade, "DeepTutor: An effective, online intelligent tutoring system that promotes deep learning," in *Proc. AAAI Conf. Artif. Intell.*, 2015, vol. 29, no. 1, pp. 4294–4295, doi: 10.1609/aaai.v29i1.9269.

[53] A. C. Graesser, S. Lu, G. T. Jackson, H. H. Mitchell, M. Ventura, A. Olney, and M. M. Louwerse, "AutoTutor: A tutor with dialogue in natural language," *Behav. Res. Methods, Instrum., Comput.*, vol. 36, no. 2, pp. 180–192, May 2004, doi: 10.3758/bf03195563.

[54] Y. Fang, Z. Ren, X. Hu, and A. C. Graesser, "A meta-analysis of the effectiveness of ALEKS on learning," *Educ. Psychol.*, vol. 39, no. 10, pp. 1278–1292, Nov. 2018, doi: 10.1080/01443410.2018.1495829.

[55] W. Cui, Z. Xue, and K.-P. Thai, "Performance comparison of an AI-based adaptive learning system in China," in *Proc. Chin. Autom. Congr. (CAC)*, Nov. 2018, pp. 3170–3175, doi: 10.1109/CAC.2018.8623327.

[56] J. Duerrwaechter, T. Kuhn, F. Meyer, A. Beck, and C.-D. Munz, "PoUnce: A framework for automatized uncertainty quantification simulations on high-performance clusters," *J. Open Source Softw.*, vol. 8, no. 82, p. 4683, Feb. 2023, doi: 10.21105/joss.04683.

[57] J. J. Sophia and T. P. Jacob, "EDUBOT-A chatbot for education in COVID-19 pandemic and VQAbot comparison," in *Proc. 2nd Int. Conf. Electron. Sustain. Commun. Syst. (ICESC)*, Coimbatore, India, Aug. 2021, pp. 1707–1714, doi: 10.1109/ICESC51422.2021.9532611.

[58] R. Gordon. *Explained: Levels of Autonomy in Self-Driving Cars*. MIT CSAIL. Accessed: Jul. 24, 2024. [Online]. Available: https://www.csail.mit.edu/news/explained-levels-autonomy-self-driving-cars

[59] M. R. Morris, J. Sohl-Dickstein, N. Fiedel, T. Warkentin, A. Dafoe, A. Faust, C. Farabet, and S. Legg, "Levels of AGI for operationalizing progress on the path to AGI," 2023, *arXiv:2311.02462*.

[60] A. E. Austin, "Creating a bridge to the future: Preparing new faculty to face changing expectations in a shifting context," *Rev. Higher Educ.*, vol. 26, no. 2, pp. 119–144, Dec. 2003, doi: 10.1353/rhe.2002.0031.

[61] A. Alexander, M. Karvonen, J. Ulrich, T. Davis, and A. Wade, "Community college faculty competencies," *Community College J. Res. Pract.*, vol. 36, no. 11, pp. 849–862, Aug. 2012, doi: 10.1080/10668926.2010.515511.
[62] C. V. Felix, "The role of the teacher and AI in education," in *International Perspectives on the Role of Technology in Humanizing Higher Education*. U.K.: Emerald Publishing Limited, Nov. 2020, pp. 33–48, doi: 10.1108/s2055-364120200000033003.
[63] J. Shen, N. Tenenholtz, J. Brian Hall, D. Alvarez-Melis, and N. Fusi, "Tag-LLM: Repurposing general-purpose LLMs for specialized domains," 2024, *arXiv:2402.05140*.
[64] H. Liu, D. Tam, M. Muqeeth, J. Mohta, T. Huang, M. Bansal, and C. Raffel, "Few-shot parameter-efficient fine-tuning is better and cheaper than in-context learning," 2022, *arXiv:2205.05638*.
[65] P. Lewis, E. Perez, A. Piktus, F. Petroni, V. Karpukhin, N. Goyal, H. Küttler, M. Lewis, W. Yih, T. Rocktäschel, S. Riedel, and D. Kiela, "Retrieval-augmented generation for knowledge-intensive NLP tasks," in *Proc. 34th Conf. Neural Inf. Process. Syst. (NeurIPS)*, Vancouver, BC, Canada, 2020, pp. 9459–9474.
[66] D. Amodei, C. Olah, J. Steinhardt, P. Christiano, J. Schulman, and D. Mané, "Concrete problems in AI safety," 2016, *arXiv:1606.06565*.
[67] H. Lee, S. Hong, J. Park, T. Kim, G. Kim, and J.-W. Ha, "KoSBI: A dataset for mitigating social bias risks towards safer large language model applications," in *Proc. 61st Annu. Meeting Assoc. Comput. Linguistics*, 2023, pp. 208–244, doi: 10.18653/v1/2023.acl-industry.21.
[68] X. Wu, L. Xiao, Y. Sun, J. Zhang, T. Ma, and L. He, "A survey of human-in-the-loop for machine learning," *Future Gener. Comput. Syst.*, vol. 135, pp. 364–381, Oct. 2022.
[69] J. Chen, J. Yoon, S. Ebrahimi, S. O. Arik, T. Pfister, and S. Jha, "Adaptation with self-evaluation to improve selective prediction in LLMs," 2023, *arXiv:2310.11689*.
[70] D. Garisto, "How cutting-edge computer chips are speeding up the AI revolution," *Nature*, vol. 630, no. 8017, pp. 544–546, Jun. 2024. [Online]. Available: https://www.nature.com/articles/d41586-024-01544-0
[71] N. C. Thompson, K. Greenewald, K. Lee, and G. F. Manso, "The computational limits of deep learning," MIT Initiative Digit. Economy Res. Brief, USA, Tech. Rep., 2020, pp. 1–4, vol. 4. [Online]. Available: https://ide.mit.edu/wp-content/uploads/2020/09/RBN.Thompson.pdf
[72] "AI hardware has an energy problem," *Nat. Electron.*, vol. 6, p. 463, Jul. 2023, doi: 10.1038/s41928-023-01014-x.
[73] R. Metz. *OpenAI Scale Ranks Progress Toward 'Human-Level' Problem Solving*. Accessed: Jul. 18, 2024. [Online]. Available: https://www.bloomberg.com/news/articles/2024-07-11/openai-sets-levels-to-track-progress-toward-superintelligent-ai
[74] Samsung Res., Seoul, South Korea. (Dec. 1, 2020). *6G: The Next Hyper-Connected Experience for All*. [Online]. Available: https://cdn.codeground.org/nsr/downloads/researchareas/20201201_6G_Vision_web.pdf
[75] P.-A. Blanche, A. Bablumian, R. Voorakaranam, C. Christenson, W. Lin, T. Gu, D. Flores, P. Wang, W.-Y. Hsieh, M. Kathaperumal, B. Rachwal, O. Siddiqui, J. Thomas, R. A. Norwood, M. Yamamoto, and N. Peyghambarian, "Holographic three-dimensional telepresence using large-area photorefractive polymer," *Nature*, vol. 468, no. 7320, pp. 80–83, Nov. 2010, doi: 10.1038/nature09521.
[76] L. Guo, D. Wang, F. Gu, Y. Li, Y. Wang, and R. Zhou, "Evolution and trends in intelligent tutoring systems research: A multidisciplinary and scientometric view," *Asia Pacific Educ. Rev.*, vol. 22, no. 3, pp. 441–461, May 2021, doi: 10.1007/s12564-021-09697-7.
[77] R. S. Baker, "Stupid tutoring systems, intelligent humans," *Int. J. Artif. Intell. Educ.*, vol. 26, no. 2, pp. 600–614, Feb. 2016, doi: 10.1007/s40593-016-0105-0.
[78] D. Prasse, M. Webb, S. Parent, Y. Goda, M Yamada, P. Fisser, M. Deschênes, H. Li, A. Raynault, S. Hopper, and C. Yeung, "Thematic working group 4—Fostering self-regulatory skills in learners in digital learning environments," in *Proc. Moving Forward New Educ. Realities Digit. Era (EDUsummIT)*, May 2023, pp. 26–33.
[79] B. J. Zimmerman, "Becoming a self-regulated learner: Which are the key subprocesses?" *Contemp. Educ. Psychol.*, vol. 11, no. 4, pp. 307–313, Oct. 1986, doi: 10.1016/0361-476x(86)90027-5.
[80] Dept. Educ. *Generative AI: Call for Evidence Summary of Responses*. Accessed: Jul. 17, 2024. [Online]. Available: https://www.gov.uk/government/calls-for-evidence/generative-artificial-intelligence-in-education-call-for-evidence
[81] J. Dean. (2022). *Face-to-Face Interaction Enhances Learning, Innovation*. Cornell Chronicle. Accessed: Jul. 16, 2024. [Online]. Available: https://news.cornell.edu/stories/2022/03/face-face-interaction-enhances-learning-innovation
[82] J. H. Wilson, R. G. Ryan, and J. L. Pugh, "Professor–student rapport scale predicts student outcomes," *Teaching Psychol.*, vol. 37, no. 4, pp. 246–251, Sep. 2010, doi: 10.1080/00986283.2010.510976.
[83] H. J. Walberg and S.-L. Tsai, "Matthew effects in education," *Amer. Educ. Res. J.*, vol. 20, no. 3, pp. 359–373, Jan. 1983.
[84] J. Reich, *Failure to Disrupt: Why Technology Alone Can't Transform Education*. Cambridge, MA, USA: Harvard Univ. Press, 2020.
[85] W. H. Stewart, "A global crash-course in teaching and learning online: A thematic review of empirical emergency remote teaching (ERT) studies in higher education during year 1 of COVID-19," *Open Praxis*, vol. 13, no. 1, p. 89, Mar. 2021, doi: 10.5944/openpraxis.13.1.1177.
[86] A. Eyles, S. Gibbons, and P. Montebruno, "COVID-19 school shutdowns: What will they do to our children's education?" London School Ecomonics Political Sci., London, U.K., CEPCOVID Tech. Rep. 19-001, 2020. Accessed: Jul. 5, 2024. [Online]. Available: http://cep.lse.ac.uk/pubs/download/cepcovid-19-001.pdf
[87] A. R. Golden, E. N. Srisarajivakul, A. J. Hasselle, R. A. Pfund, and J. Knox, "What was a gap is now a chasm: Remote schooling, the digital divide, and educational inequities resulting from the COVID-19 pandemic," *Current Opinion Psychol.*, vol. 52, Aug. 2023, Art. no. 101632, doi: 10.1016/j.copsyc.2023.101632.
[88] L. Czerniewicz. *What We Learnt From 'Going Online' During University Shutdowns in South Africa*. Edtech Newslett. Accessed: Jul. 10, 2024. [Online]. Available: https://onedtech.philhillaa.com/p/what-we-learnt-from-going-online-during-university-shutdowns-in-south-africa
[89] K. Rao, "Inclusive instructional design: Applying UDL to online learning," *J. Appl. Instructional Design*, vol. 10, no. 1, pp. 83–96, 2021, doi: 10.51869/101/kr.
[90] World Econ. Forum, Geneva, Switzerland. (Apr. 2024). *Shaping the Future of Learning: The Role of AI in Education 4.0*. [Online]. Available: https://www.weforum.org/publications/shaping-the-future-of-learning-the-role-of-ai-in-education-4-0/
[91] J. Bieser, "Creative through AI: How artificial intelligence can support the development of new ideas," GDI Gottlieb Duttweiler Inst., Rüschlikon, Switzerland, Tech. Rep. 4610307, 2022.
[92] CAST, Lynnfield, MA, USA. (2018). *Universal Design for Learning (UDL) Guidelines Version 2.2*. [Online]. Available: https://udlguidelines.cast.org/
[93] F. Martin and D. U. Bolliger, "Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment," *Online Learn.*, vol. 22, no. 1, pp. 205–222, Mar. 2018, doi: 10.24059/olj.v22i1.1092.
[94] X. Chen, H. Xie, D. Zou, and G.-J. Hwang, "Application and theory gaps during the rise of artificial intelligence in education," *Comput. Educ., Artif. Intell.*, vol. 1, Jan. 2020, Art. no. 100002, doi: 10.1016/j.caeai.2020.100002.
[95] R. Garg, R. Patel, and L. Lalbahadur, "AI in school education: Uncovering possibilities and navigating challenges," *Nat. Campano*, vol. 28, no. 1, pp. 1026–1032, 2024.
[96] P. Dillenbourg, "Design for classroom orchestration," *Comput. Educ.*, vol. 69, pp. 485–492, Nov. 2013, doi: 10.1016/j.compedu.2013.04.013.
[97] I. Celik, "Towards intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education," *Comput. Hum. Behav.*, vol. 138, Jan. 2023, Art. no. 107468, doi: 10.1016/j.chb.2022.107468.
[98] J. Koh, M. Cowling, M. Jha, and K. N. Sim, "The human teacher, the AI teacher and the AIed-teacher relationship," *J. Higher Educ. Theory Pract.*, vol. 23, no. 17, pp. 200–212, Nov. 2023, doi: 10.33423/jhetp.v23i17.6543.
[99] Z. Slimi and B. Villarejo Carballido, "Navigating the ethical challenges of artificial intelligence in higher education: An analysis of seven global AI ethics policies," *TEM J.*, vol. 12, no. 2, pp. 590–602, May 2023, doi: 10.18421/tem122-02.
[100] Y. Wang, S. Lu, and D. Harter, "Multi-sensor eye-tracking systems and tools for capturing student attention and understanding engagement in learning: A review," *IEEE Sensors J.*, vol. 21, no. 20, pp. 22402–22413, Oct. 2021, doi: 10.1109/JSEN.2021.3105706.
[101] I. H. Cho and H. J. Park, "Video lesson system and method for providing feedback information based on changes in pupils," KR Patent 10-2020-0 099 383, Mar. 2, 2020.

[102] I. H. Cho and G. W. Jeong, "Video lesson system and method for monitoring user's attention based on user's visual behavior," KR Patent 10-2020-0 099 370, Feb. 17, 2023.
[103] T. Wang, B. D. Lund, A. Marengo, A. Pagano, N. R. Mannuru, Z. A. Teel, and J. Pange, "Exploring the potential impact of artificial intelligence (AI) on international students in higher education: Generative AI, chatbots, analytics, and international student success," *Appl. Sci.*, vol. 13, no. 11, p. 6716, May 2023, doi: 10.3390/app13116716.
[104] H. Yoo, J. Jang, H. Oh, and I. Park, "The potentials and trends of holography in education: A scoping review," *Comput. Educ.*, vol. 186, Sep. 2022, Art. no. 104533, doi: 10.1016/j.compedu.2022.104533.

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