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Implementation of Artificial Intelligence in engineering teaching and learning

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Abstract. This paper is concerned with increasing the efficiency of teaching and learning in engineering by applying artificial intelligence (AI) techniques and technologies. An approach to realize the personalized intelligent tutorial system (ITS) is proposed, which would be more oriented to the specifics of engineering teaching. The key idea is to create a subsystem for generating personalized tasks for students in the form of a decision module based on binary and fuzzy logic rules. Intelligent tutoring systems are characterized by storing three types of knowledge base: a) domain knowledge, b) learner knowledge, and c) pedagogical knowledge. It is these types of knowledge that also determine the three main parts of the ITS architecture: a) domain knowledge creation/development applications, learner knowledge assessment modules, and pedagogical knowledge creation/development modules.

Keywords: engineering teaching and learning, artificial intelligence, tutorial-type teaching, personalized study tasks, knowledge estimation.

1. Introduction

At the current stage, science, technology, and engineering research benefit from artificial intelligence in various fields: autonomous cars, collaborative robots, unmanned aircraft systems, supervised car manufacturing systems, management of large amounts of data, machine optimization, and even the design of new materials. Therefore, we, the teachers in the field of engineering, must sensitize students to the potential of artificial intelligence, teach them the fundamentals necessary for this field of study, and guide them in applying these technologies based on new

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algorithms to the development of real engineering projects, as necessary aspects within modern engineering study programs.

It should be noted that the impact of artificial intelligence in engineering education is not limited to the application of a set of new resources to solve specific engineering problems, but this concept of "AI-assisted engineering education" must be looked at more broadly: towards capitalizing on artificial intelligence techniques and resources to improve the entire teaching-learning process in higher education, especially about scientific and technological studies in all areas of educational practice, from the planning and organization of teaching programs and courses, through implementation and follow-up, to the final evaluation of learning outcomes and outcomes.

In this paper, we will focus on AI techniques, which could support the teaching-learning process in engineering, helping to promote more personalized education, streamline learning, support curriculum planning, and improve processes such as student assessment. We will present examples of good practices of artificial intelligence processes, which could be implemented in many engineering programs/curricula to provide students with the fundamentals of artificial intelligence and to illustrate its potential applications in their concrete areas of specialization.

2. Developing/carrying out teaching and learning with the help of tutorials using AI

2.1.The need for teaching and learning

Educational software with an artificial intelligence component is an intelligent tutoring system (ITS). The software monitors the student's activity, modifying their comments and providing contextualized suggestions. Based on a student's performance and other cognitive and noncognitive characteristics, the software can predict strengths and weaknesses and recommend further practice.

The main purpose of assessments in traditional systems is to improve the training and education of students. A key objective of formative assessment is to facilitate student learning by establishing the student as an upright, resourceful, and self-reflective member of the educational community. Individualized instruction and real-world practice are common in formative assessment-based classrooms [14].

The lack of standardization and the less rigorous approach of formative assessment than summative assessment is a fundamental shortcoming of this paradigm.

As a result, the quality of assessment resources and results may suffer. Given that the accuracy of a student's diagnosis depends on the validity and reliability of the assessment data, and that the diagnosis informs educational support, a weak link in the chain (i.e., valid and reliable assessment data) would have a negative impact on the effectiveness of this support. In other words, the quality of the data used to build the student's model is critical to the performance of an intelligent system to perform its task (i.e., inferences about what the student knows and can do).

Traditional tutoring systems that use formative assessment can extract a lot of information about students [14]. All interactions between students and the system are recorded as evidence, which can take various forms and granularities.
Therefore, there may be problems related to the effective modeling of students' knowledge in such diverse environments, which adds to the lack of standardization of formative assessment methods in traditional intelligent systems.
Regardless of the measurement method chosen, it presents several psychometric problems (e.g., modeling a wide range of student characteristics, such as talents and aptitudes).
Currently, AI-based tutoring systems are largely limited to research institutions, but the demand for accountability (e.g., standards and examination norms) increases when these systems are introduced in universities.
Tutorial systems used in a controlled setting are not subject to the same strict regulations (such as accountability requirements) as those used in a real classroom. This disconnection from real classrooms helps explain why their models have not focused heavily on summative assessment methods and, to some extent, why they have not been widely adopted [16].
What are the needs of ITS? There are two main reasons [11]: research and practical implementation. From a research point of view, it is essential to learn more about the procedures that make an educational commitment successful from a purely academic point of view.
ITS research sits at the intersection of cognitive psychology, artificial intelligence, and education, making it fertile ground for testing many theories in each field. Therefore, the development of an ITS can contribute to the development of more robust theories of knowledge.
From a practical point of view, ITSs allow for many outcomes that would be difficult or impossible to achieve with human teachers due to cost and accessibility. There is broad agreement that self-paced instruction is the most productive method of teaching in most cases.
The ability to provide personalized training is a crucial benefit of ITSs.
By assigning an ITS to each student in a class, the university can offer this type of tutoring while benefiting from the benefits of a classroom setting.
ITS could provide the student with real-time feedback on their performance. Because tutoring is most successful when it responds directly to the needs of students, personalized and timely feedback is vital.

2.2. The influence of teaching and learning

Especially in digital environments, smart tutoring systems can significantly affect students' learning abilities. Digital applications provide students with personalized learning experiences through deep learning algorithms, although ITS are not yet widely implemented in educational contexts.
Using machine learning algorithms to shape student learning will allow teachers to create digital programs without AI [13].

The value of this technology lies in the fact that it can be tailored to meet the needs of every user, from the most experienced teacher to the youngest student. If this is achieved, ITS will make great strides towards adoption in education and higher education environments.

People are complex and require individualized approaches to learning, which is a significant obstacle in educating children of all ages. This is in contradiction with standardized tests and the "one measure for all" philosophy that underpins many educational institutions today [13].

Due to the inability of the existing model to identify and highlight learners' unique strengths, some students have been left behind. Many of the problems affecting the education system today could be alleviated with the help of ITSs, which have the potential to play a key role in the future of the sector.

Artificial intelligence (AI) and related systems, such as intelligent tutoring systems (ITS), directly address this problem by promoting an educational framework where students' unique strengths and interests are further valued.

ITSs are just one example of revolutionary new tools based on AI technology that will soon become a standard feature in today's classrooms and online learning spaces. Many countries are transitioning in this direction because experts agree that it is the best approach to education [14].

Analysis of several information sources shows that smart tutoring systems can have the following benefits [5]:

- They can be available at any time, including late at night, the night before a test.
- It helps teachers and programmers improve their methods by giving them access to real-time information.
- Reduces dependence on human resources;
- They can allow students to demonstrate their understanding by having them describe what they already know and then respond appropriately according to their level of understanding;
- They can facilitate the development of adapted curricula by teachers;
- Produce better results on tests than more conventional methods, especially for students learning English as a second language, who come from low-income families or who have specific educational needs;
- They allow for instant yes/no feedback, individualized task selection, on-demand suggestions, and reinforcement of mastered learning.

3. AI-based implementation on the MOODLE online platform

The MOODLE online training platform is one of the most widespread in engineering training [19, 20, 21], and the idea of extending its performance by implementing artificial intelligence capabilities arises. Various case studies, in which the well-known ChatGPT system was implemented and explored on a Moodle elearning platform, show that [3,11]:

- There are several use cases that can help predict user requests and improve the quality of feedback provided by ChatGPT in the context of Moodle.

• The already existing experiments can inspire other intelligent applications of ChatGPT on the Moodle platform.

It is well known that ChatGPT has features such as reminder aspects, supportive communication, tracking corrections, etc. Therefore, it is important to clarify the capabilities of ChatGPT, which could help end users (course creators) better understand how and where to apply this "tool".

We will present the following five capabilities of ChatGPT, which are students for the education and training sectors [3, 11].

• *Contextual conversational ability.* Contextual conversation refers to ChatGPT's ability to provide an interactive conversational experience that keeps students engaged and motivated.

This ChatGPT ability can understand the context of a conversation and respond accordingly, taking into account factors such as the student's string of previous questions, the topic discussed, and the student's level of understanding.

So, this ability to understand the context and respond to it is essential for providing effective feedback and personalized support to students in a tutorial learning management system.

• *Responsiveness to feedback.* The ChatGPT system can provide feedback, which is both reflective and diagnostic, helping students understand not only what they did wrong, but also why they did wrong and how they can improve in the future. This type of feedback can be especially helpful for students who are working with a particular concept or skill, as it can help them identify and address the root cause of the problem.

• *Analytical capacity.* This capability is based on machine learning (ML), which is a branch of AI that uses algorithms and statistical models to enable computers to learn from data without programming. In other words, ML is the backbone of many AI approaches and is analytical at its core.

Large natural language models (NLPs) are a specific type of ML model designed to generate human-like text by predicting the probability of a sequence of words given certain input data.

It is known that ChatGPT mainly benefits from NLPs that train neural network models with enormous resources and large-scale data using language models.

At the same time, it should be noted that ChatGPT focuses on natural language and is trained on a massive amount of texts, which is why ChatGPT's current abilities in concrete areas, for example, mathematics are significantly below the level of an average graduate student of mathematics or that ChatGPT provides incorrect answers to mathematical or logical problems, which have defined solutions, instead of probabilistic.

• *Adaptive tutoring capability.* Smart adaptive tutoring environments should consider cognitive, metacognitive, and affective factors about the student before making teaching decisions. ChatGPT is an example of such an environment that can adapt to the individuality of each user who sends directions, satisfying all three factors.

As mentioned, ChatGPT adjusts its answers based on the user's previous questions, the topic discussed, and the user's level of understanding.

For example, if a student asks a question about an unfamiliar topic, ChatGPT can provide a simple and clear explanation to help them understand. In contrast, if a student asks a more advanced question, ChatGPT can provide a more detailed and nuanced answer.

In addition, a student can ask to increase or decrease the difficulty of responses to their requests. These skills are embedded in ChatGPT as adaptive help schemes, which can teach students how to request and use help effectively and promote a positive attitude towards asking for help in general.

- *Multilingual ability.* ChatGPT's multilingual capability can make it easier for students and teachers to communicate in different languages and cultures, opening up new opportunities for learning and collaboration globally. ChatGPT's performance of multilingual summarization, which consists of providing a summary in the target language for a long document in a source other than the original language, it has been shown that ChatGPT initially prefers to produce long summaries with more detailed information, but with the help of an interactive dialogue, it can balance between informativeness and conciseness and significantly improve its performance.

4. Intelligent tutorial system implementation methodology

Knowing that ChatGPT provides incorrect answers to mathematical, logical, and even engineering problems, we propose a vision of the authors of a tutorial system based on artificial intelligence, without diminishing the importance and performance of ChatGPT.

Researching several information sources, we found that intelligent tutoring systems are characterized by the fact that they store three types of knowledge base [1,4-9]: a) knowledge about the field, b) knowledge about the learners, and c) pedagogical knowledge.

It is precisely these types of knowledge that determine the three main parts of the ITS architecture: a) applications for creating/developing knowledge in the field, modules for assessing students' knowledge, and modules for creating/developing pedagogical knowledge.

Starting from this finding, we propose the scheme of an ITS with the flow of information in this system (see Fig. 1).

We will not describe this vision in detail, but we will limit ourselves to the key component of ITS – the intelligent generator of personalized tasks for each student. These capabilities provide three ways in which a student can consider a learning task: a) the overview board that lists all available tasks, b) currently recommended resources, and c) the calendar for the appropriation of resources.

We propose that the task generator (Fig. 2) be made as a decision-making system with a base of mixed rules (with binary and fuzzy logic). Input information is the components of the knowledge in the domain and the estimation of the knowledge possession of each student. The results will be a personalized to-do list for each student at a specific stage of the study process. The module on the formation of

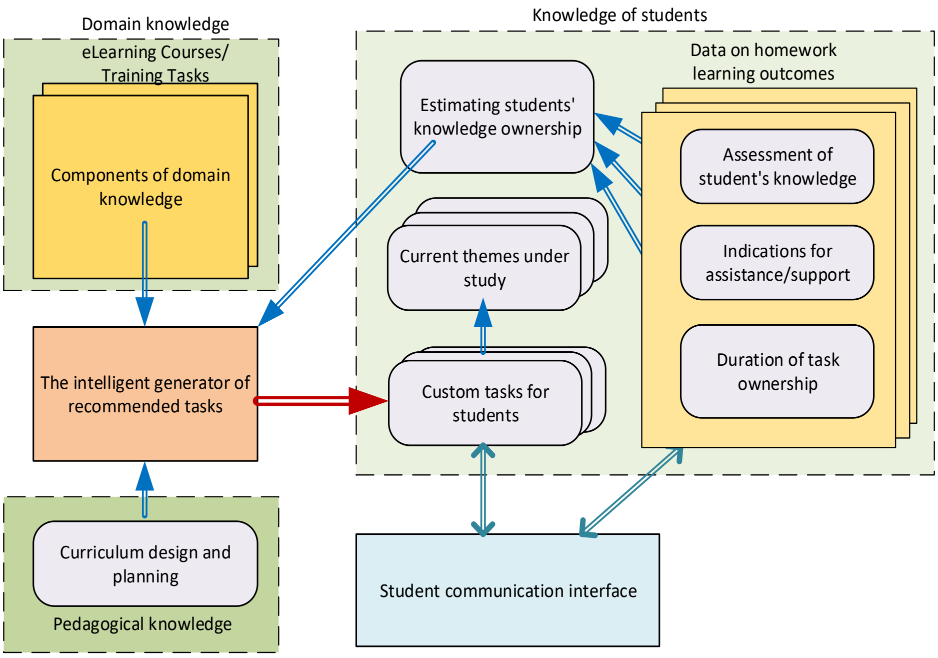

Fig 1. The flow of data/information in the AI-based tutorial system.

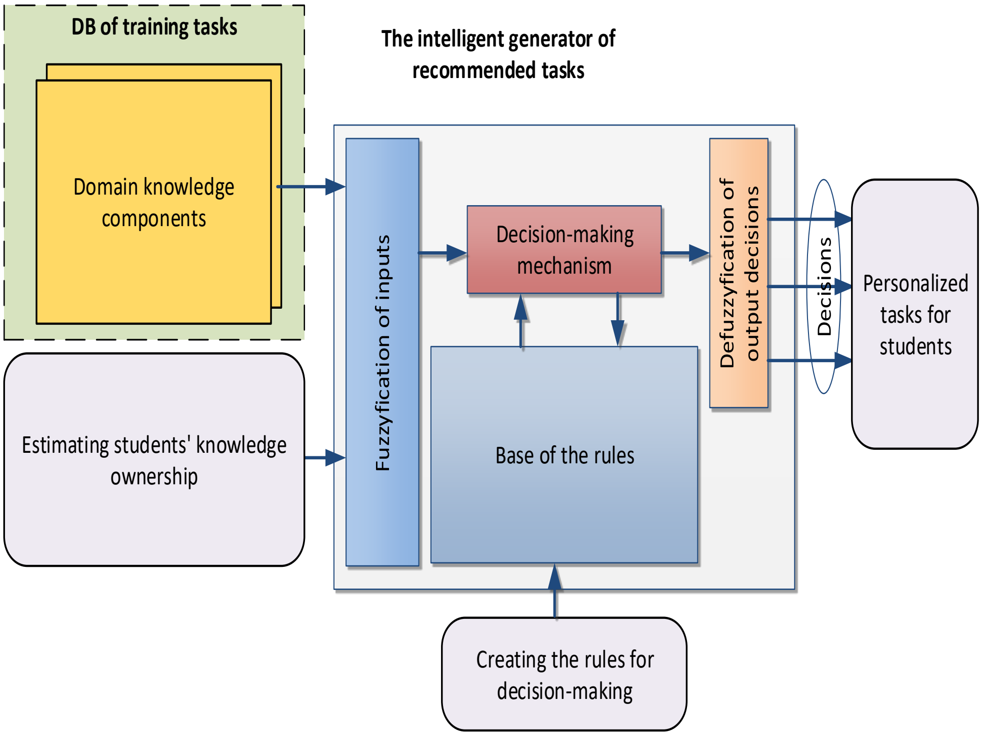

Fig 2. The data/information flow of the generator of recommended tasks.

individual tasks for students presents a heuristic algorithm managed by decision-making rules. These rules are created and dynamically developed/modified by accredited teachers for the evolution of ITS.

The proposed vision refers to **the case of self-regulated study** (more characteristic of the engineering university environment), where tasks and recommendations have a more central role, helping students to go through the material efficiently, but under their own control. Between these two cases is the intelligent set of recommendations, in which the student can choose, and therefore allows some semblance of autonomy.

The student model currently takes into account three types of features:

- the student's performance scores reported by tasks,
- assistance/support/support of the student reported on tasks;
- the time it takes to complete each task.

All of these features are derived from assignment sessions, which are dynamically constructed by the student communication subsystem from the student's learning records.

Interaction model/student interface. The way of interaction/interface of the student with the ITS also plays an important role in streamlining the training in the engineering field. It is obvious that the traditional approach to student-ITS interaction would give a minimum of efficiency despite the advantages of ITS. Although there are several approaches, in the opinion of the authors, the following use deserves greater attention: a) natural/pseudo-natural language; b) VR and AR virtual reality; c) tele-presence.

Due to a lack of space, we will make a brief review, showing the perspectives and limitations of these approaches.

Natural/pseudonatural language. Natural language processing technology has made a breakthrough in digital education. Currently, natural language processing (NLP) is used in the classroom for various purposes, including grading essays and generating feedback, generating questions, generating examples, etc. The use of NLP in online literacy initiatives is increasing. It also has significant potential in printing programs, where printed products are created with the help of AI. There are newer and more complex NLP tools, many of which are free and open-source (for example, the latest NLP technology, Transformer, has several open-source designs). We also see that neural technologies perform human-like tasks on natural language data with significantly higher accuracy. Some good uses of natural language processing (NLP) tools include:

- Personalized reading plans: Using natural language processing (NLP) technology, we can provide students with reading materials that are more appropriate to their skill level. There is open text data on the internet that can be used by natural language processing algorithms to determine text reading difficulties, which allows us to quickly and easily create software that provides students with properly classified reading materials.

- Feedback on essays: OpenAI and similar platforms have made it possible to create software that provides students with objective feedback. The software can

provide the student with direct, formative information. The formation of such systems would require creative data collection, but if done correctly, it could lead to new applications that reduce the burden on teachers.
- Question generation: It is possible to create a wide range of test questions using pre-existing learning resources. Despite the novelty of this field, academic research has created standards for assessing the quality of question generation models.
- Generating examples: We can use natural language processing to generate content based on criteria. Using this technological skill, we can produce examples of solved math problems, construct sentences that illustrate multiple ways of using the same term, produce literature summarization examples, and so on.

Benefits and uses of NLP: a) NLP helps in learning and understanding. For each student and subject, the student's learning rate varies. Some students have unique requirements that require various instructional strategies. b) Answering questions Essay assessments, tests and flashcards are highly valued by students and teachers, but their manual preparation can be intimidating for teachers with a high workload.

c) Using NLP, it can have questions and answers created for study materials. It also measures how well a student's written comments fit with the course content. A student's reading level and learning rate, among other factors, can be used to tailor questions and assessment. It saves time for overworked teachers by providing feedback on essay content in four key areas: grammar, structure, semantics, and logic.

With all these advantages and benefits, NLP is very complicated when it comes to training students with different languages than English.

VR and AR virtual reality. The advent of electronics marked a significant leap in HMI design, introducing visual buttons, switches, and indicators, allowing for more nuanced control and communication with machines. Today, technological progress is challenging the once distinct boundaries between humans and machines, leading to a new era in which integration and interaction with machines are more transparent and interconnected, reflecting both the opportunities and challenges posed by such close integration between humans and technology.

The usefulness of HMIs has increased significantly with the advent of graphic displays, along with the evolution of touchscreen technology. Microcontrollers have improved the ability of machines to store preferences and simplify operations, allowing for quick and efficient mode selection. The development of motor control and force feedback has brought new levels of precision to the operation of machines. However, the lure of innovative technology does not necessarily equate to efficiency. Early virtual reality (VR) systems, for example, faced problems with real-time head tracking, leading to user discomfort due to the disconnect between expected and actual visual feedback.

Effective HMIs prioritize intuitiveness and minimal training requirements, increasing their evolutionary utility. Advancements such as brighter displays and touchscreens have transformed user interaction, although there have been notable challenges, such as recalibration and limited touch capabilities in early releases. The shift to touch-enabled technology has significantly advanced HMI functionality, exemplified by the widespread adoption of smartphones and tablets. The intuitive nature of these devices allows for rapid learning and operation without in-depth training, even among children, who often outperform adults in mastering new technologies.

A key aspect of HMI design is to ensure operator comfort and minimise fatigue over long periods of use. In addition, HMIs, such as aviation head-up displays, demonstrate the importance of maintaining operator focus and comfort during extended sessions. Design considerations must also address the risk of repetitive stress injuries, emphasizing the importance of ergonomics in the design of interfaces to support user health and productivity.

Modern virtual reality (VR) and augmented reality (AR) systems are the spearhead of technology. Both VR and AR excel at creating immersive experiences, improving learning and training environments, revolutionizing entertainment, and providing new ways to interact with digital content. AR presents a safer alternative by overlaying digital information on top of the real world, allowing users to actually see details and/or obstacles. This technology is particularly beneficial not only in specialized fields such as aerospace, but also in training, in the study of complex systems. These AR systems not only improve the performance of task instruction and execution, but also allow for the detection of defects beyond human capability. However, for remote control applications such as drone piloting, HMI must strike a balance between sensitivity and robustness, ensuring reliability in conditions such as nearby explosions or unintentional operator movements, with safety mechanisms in place to prevent unintended actions. The development of neural interfaces improves mobility and paves the way for direct brain-computer communication. Next-generation HMIs now offer immersive experiences and improved control, and future innovations promise to further integrate technology into human experiences. As HMIs advance, they promise to expand human capabilities and improve the efficiency of university teaching/training.

Telepresence. Telepresence refers to a set of modern technologies that allow a person to feel as if they are present, to give the impression of being present, or to have an effect, through telerobotics, in a place other than their actual location [14, 15]. Telepresence has been driven by the need to expand natural human sensorimotor competence and enable action and perception from a distance, in environments that are extremely difficult for humans to access or in which it is extremely dangerous to operate, such as space, disastrous areas with strong radiation, and micro- and nanoscale environments.

Thanks to revolutionary communication technologies, which allow for very low latency and very high reliability, telepresence is making its presence felt in several sectors of human life, promising to reduce costs in offering a wide range of services, meet the needs of society, and democratize access to various services (including medical services) [14, 15].

It already allows remote operators to act as if they were present in a remote control cabin/room, pilots to operate drones, specialized workers to operate heavy equipment, drive agricultural machinery or drive surface vehicles. As the horizon of telepresence expands due to the acceleration of medium technologies (such as communications and robotics), new challenges (such as security and agility) are emerging that would require active conversation and collaboration among multiple stakeholders, including leaders from academia, industry, healthcare, and regulatory.

5. Conclusions

It has been found that teaching and learning in engineering using personalized tutorials through the application of artificial intelligence techniques and technologies will lead to increased efficiency of teaching and learning in engineering. It has been shown that making the custom tutorial system on the Moodle platform by augmenting ChatGPT's capabilities cannot meet the needs of engineering teaching. A different approach was proposed for the implementation of the personalized tutorial system, which would be more oriented to the specifics of engineering teaching. The key idea consists of creating a subsystem for generating personalized tasks for students in the form of a decision-making mode based on binary and fuzzy logic rules. These decision-making rules are created, modified/developed by accredited teachers, which will ensure the evolution of the personalized tutorial system.

At the same time, it is shown that the efficiency of the procedures presented can be amplified, taking into account the side of the student's interaction with the teaching/learning tools. Research and development in the field of neural interfaces have already made significant progress in the last decade, providing new mobility and functioning possibilities for people with disabilities caused by accidents or congenital conditions.

Advances in HMI interfaces have evolved from basic tools to advanced systems that blur the boundaries between technology and biology. Early mechanical controls evolved into sophisticated electronic interfaces, providing precise control and feedback. Virtual systems not only improve the performance of instructing and executing tasks, but also allow for the detection of defects beyond human capability. However, for remote control applications such as drone piloting, HMI must strike a balance between sensitivity and robustness, ensuring reliability in conditions such as nearby explosions or unintentional operator movements, with safety mechanisms in place to prevent unintended actions. The development of neural interfaces improves mobility and paves the way for direct brain-computer communication. Next-generation HMIs now offer immersive experiences and improved control, and future innovations promise to further integrate technology into human experiences. As HMIs advance, they promise to expand human capabilities and improve the efficiency of university teaching/training.

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