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Teaching and Learning of Mathematical Modelling for College Students in the Context of Artificial Intelligence

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Abstract: *This paper delves into the problem of conducting mathematics modelling education using artificial intelligence technology, describing the cooperative model and difficulties in this integration. The following four types of system upgrading were suggested: improving curriculum arrangement, nurturing a revolutionary way of thinking, building experience education platforms, and promoting the conversion of teaching roles. Moreover, the paper explores primary challenges in balancing AI with educational theories, promoting students' motivation and self-determined learning, data privacy and ethics, and discusses how to provide individualized solutions to them.*

Keywords: *Mathematical Modelling, Artificial Intelligence, College Students' Mathematical Modelling Ability*

1. Introduction

Artificial intelligence technology's rapid progress promotes social productivity and the education world, which results in college education moving towards intelligence and digitality. AI technology's wide-range use accelerates the integration of science and technology with industry and creates a new requirement for talent cultivation. Now, it is required that outstanding young people should have interprofessional knowledge, actual skills, and innovative ability. Mathematical modeling plays a pivotal role between mathematical theory and real problems. It means that mathematical modeling teaching and learning mode reform has become a necessary subject of research in the era of AI.

Undoubtedly, mathematical modeling is one of the indispensable modeling techniques that convert real-world problems into mathematical models that can be solved by mathematical modeling methods. Mathematical modeling works to represent the real-world complex systems using mathematical language, for forecasting, optimization, and decision making[1]. The core of AI technology can mainly be attributed to mathematical modeling. For instance, in machine learning, there are statistical models involved, and neural networks incorporate optimization theories. On the other hand, the increasing presence of the big data and multiple sources of information requires that the modelers should know how to integrate data, algorithms and domain knowledge for applying AI in interdisciplinary practical problem solving[2], which calls for the inclusion of emerging research paradigms, such as the data-driven modeling and dynamic simulation-based system, into teaching of mathematical modeling. From a student-centered perspective, although the application of automatic code generators and graphic modeling tools has lowered the entry barrier in the field of modeling, there is still a lack of training for them in basic traditional learning skills, such as data cleaning, model validation, and model conclusions. Thus, the introduction of AI technology should be not only oriented towards model problem-solving methods, but also teaching contents and learning ways in modeling teaching and learning. For instance, Carnegie Learning's MATHia system utilizes machine learning techniques to customize learning plans. If students struggle in mathematical modelling, the system provides feedback and prompts adaptive tasks relevant to a student's response. A study indicates that, in comparison to previous outcomes, students instructed using MATHia have demonstrated a 30% improvement in tasks related to model construction and model validation[3]. Likewise, Jupyter Notebook of the University of Michigan (with an AI plug-in) provides services for intelligent code completion, visual modeling modules, and intelligent error correction to guide students through the modeling process, so students' completion rates in interdisciplinary modeling projects have grown by 40%, and overall innovativeness in the models has also increased significantly[4].

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Russell and Norvig (2020) called attention to AI technology's ability to improve the teaching process by cleverly deploying instructional technologies and robust data analysis[5]. Yet, what concrete practical guidance do we have for systematically using AI and mathematical modeling education? In this article, the goal is to explore how to foster college students' mathematical modeling ability in the age of AI, and especially focus on the application of AI technology in mathematical modeling teaching. The effectiveness of methods to improve students' modeling ability with the aid of AI technology is also intended to be explored.

2. Methodologies for Enhancing Undergraduate Mathematical Modeling Competence

2.1 Optimize the curriculum system and textbook design

Compared with the courses in the traditional era, which focused on theoretical training, the characteristics of the new era should be embodied in the mathematics modeling teaching. For example, data mining, mathematical modeling, dynamic system simulation, and other modeling techniques contain more AI technology applications. Massachusetts Institute of Technology (MIT) has the "AI+mathematical modeling" course, which gathers the machine learning library case as Kaggle and the open-source library as Tensorflow. These courses contain real-world problem-based modeling exercises, enabling students to experience the whole modeling process from collecting to building, training, and optimizing the model. In addition, the design of textbooks needs to rely on AI technology to be transformed into dynamism and interactivity. A system for automated textbook generation developed at Carnegie Mellon University auto-adapts the difficulty of cases in real time based on students' levels of understanding. Features interactive code windows that visually reveal the impact of model parameters on the results, not only enhancing the efficacy of the learning process but also providing enhanced intuitive insights into modeling logic[6]. The above successes show that the applications of AI technology and dynamic updating of cases have the potential to be developed for the future innovative mathematics modeling educational curricula, as well as for making teaching content fit more closely the real needs of society.

2.2 Foster students' creative thinking and interdisciplinary competencies

AI-supported educational platforms can also reproduce advanced situations and realize open modeling tasks to facilitate students in seeking innovative methods via AI help, which contributes to improving students' creative thinking. Establishing interdisciplinary project groups with assistance from AI cooperation platforms helps improve learners' ability to work interdisciplinarily. For instance, Stanford University has implemented a virtual laboratory application in one of the mathematical modelling courses, where students learn how various decisions influence the behavior of a system using the simulation platform driven by AI. By a repetitive trial-and-error process, they form optimal strategies. In the same vein, the Delft University of Technology develops its "AI + Engineering Modeling" project, where student teams learn to use data captured from sensors to develop strategies for smart building energy conservation. AI aids the students in fast testing of modeling hypotheses while professors help in crossing discipline barriers[7,8]. Research shows that students who engage in these programs show a 45% increase in ability to innovate and a significant increase in consciousness on how to work with interdisciplines[9].

2.3 Practical Platform and Competition-Driven Learning

As Huang et al. (2019) have stated, students who participated in competitions and practical projects improved by more than 50% in terms of problem-solving speed and model robustness[10]. Mathematical modeling competitions can mobilize students' initiative and interest. For example, participants of the Mathematical Contest in Modeling (MCM/ICM) held in the USA need to finish the modeling stage, i.e., from analyzing the question to deploying models, in 72 hours. For a common modeling task, e.g., social network sentiment modeling, advanced artificial intelligence methods (e.g., natural language processing, techniques for keyword extraction, and the Monte Carlo method for model validation) should be adopted and applied by students. Apart from competitions, practical platforms can also promote the modeling abilities of students. For instance, there is the school-enterprise cooperation platform offering realistic industry data, through which the students can practically complete the entire modeling process and also get prompt advice from a real engineer from time to time[11]. We may further develop an AI-intelligent competition platform, which could generate modeling problems dynamically

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and give instant scoring feedback, thereby cultivate students' practical modeling ability. Furthermore, colleges and universities need to create the industrial-university-research collaborative innovation laboratories in combination with enterprises, which will facilitate the use of AI modeling technologies to enter real applications and cultivate the quality of talent in terms of knowledge transfer and application.

2.4 Transformation of Teaching Roles and Enhancement of Professional Competencies

The contents of teaching and learning, teaching modes, and the professional skills of teachers are the main factors that directly affect and improve the students' mathematical modeling ability. And, with the deepening application of artificial intelligence in education, the professional status of teachers is also shifting to a comprehensive and multidisciplinary professional profile. Teachers also need to learn how to use AI tools in teaching, such as using AI-based learning analytics to track the development of student models in real time, thus allowing teachers to make immediate adaptations in teaching. From an instructional design perspective, teachers can also use the AI classroom assistant to generate immersive learning contexts, dynamically create practice exercises, and conduct online student group discussions[12]. Additionally, college teachers should actively conduct interdisciplinary studies so that they can effectively introduce the latest technology concepts to college students during their teaching process[13]. On the part of universities, an "AI + Education" certificate system could guarantee that teachers proficiently utilize one of the intelligent teaching tools. Moreover, Universities should also develop intelligent lesson planning tools based on KGs by using AI for cross-disciplinary sharing of teaching materials, facilitate the faculty members' learning and knowledge integration, and develop teaching resource pools that can be dynamically updated. Fourthly, institutions must establish an intercommunication mechanism between teaching and research, and motivate faculty to develop teaching case stories based on research findings to help increase the timeliness and interest of teaching material.

3. Challenges and Corresponding Solutions

3.1 The Challenge of Integrating Technology with Pedagogical Concepts

Related to technology, several institutions reported a lack of AI infrastructure, such as limited computing power and a lack of specialized software. As a solution, institutions can share technology with industry to implement cloud computing in teaching. Educational institutions can establish collaborative partnerships with companies offering free open-source tools, such as Google Colab and Kaggle Kernels. Alternatively, they may develop a low-code artificial intelligence modeling platform to reduce technical barriers.

On the concept of instruction, some teachers are reluctant to use AI tools because they have heard negative reports about the overall efficacy of these instructional technologies. In response to that skepticism, instructors can cite empirical studies on how much these technologies help to reduce grading time. For example, a pilot study at the University of Michigan showed that Automatic Assessment/AI grading systems like Gradescope can halve grading time for instructors and boost grading accuracy by thirty-five percent[14].

3.2 Issues of Students' Learning Motivation and Autonomous Learning Ability

The motivation in abstract modelling problems will usually decrease among the students. A model of gamified learning and rewarding system in points and virtual medals can help them be inspired in their learning. For instance, the Duolingo Math app breaks down modeling tasks into various levels, and students can obtain virtual medals once they finish particular steps, such as "data cleaning" or "model optimization", to obtain the feedback and a feeling of accomplishment in the meantime[15]. Moreover, game-based reward schemes–like dynamic rankings boards embedded in the course–could also be brought to the situation, inspired by websites like Kaggle, to appeal to students' competitive side and enthusiasm.

The lack of a weakly self-driven learning capacity may lead to a higher failure rate of students. Fortunately, a higher capacity for self-learning can be achieved with strong technological tools. The University of Sydney, Australia, takes learning analytics technologies as well as the Knewton Alta integrated system to keep tracking the students' learning situation. In case of not logging in the system

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for a long time, the email message (or texts) can be automatically sent out to remind. The individual learning resources will be suggested based on the individual's learning history and learning needs[16]. Additionally, adaptive learning pathways could be constructed automatically by using artificial intelligence (e.g., automatically configuring the next exercise's difficulty according to the previous performance[17].

3.3 Data Privacy and Ethical Issues

How to protect students' data security and privacy in schools is a rather challenging issue. The teaching platform must securely collect and thoroughly anonymize its data, such as model questionnaires and behavioral tracks. For example, the Georgia Institute of Technology in the US has taken overall efforts to protect the students' data from the view of both the technique and the location. The company that ran the online modeling system added enough noise such that no individual student can be reidentified from the data. Further, all sensitive data is kept on internal campus servers and not sent to be processed in commercial cloud services[18].

The ethics issues may be neglected when students practice AI for modeling, causing models that lead to unfair or discriminatory decisions. Ethics education is important to foster students' ethics awareness. Thus, we should make efforts to improve it by incorporating related materials into teaching programs. For instance, the chapter on "AI Ethics" has been set up in the course of mathematical modeling from the University of Cambridge, including the realistic case analysis of a biased hiring model in gender, algorithmic transparency issues, etc. The ethics will become more self-conscious to students to know more about the embedded ethical issues of the whole AI modeling work[19]. The task of the regulator is to develop an ordered ethical review mechanism. The students must submit with their modeling report a "Data Usage Statement" specifying how they used data and any relevant ethical concerns about data use. Implementing the "Data Usage Statement" ultimately keeps track of what is done during the student modeling process and helps establish that these practices remain ethically responsible during data use[20].

4. Future Outlook

4.1 Emerging Trends in AI Integration within Mathematical Modelling Education

Educational mathematics modeling is undergoing drastic changes as Deep learning and Generative AI technologies are proliferating in the current day. Personalized tutoring systems are going to have pivotal roles in future education. Language model-driven large-scale AI modelling assistants have the potential to respond to students' questions on the fly and with multi-facet advice, such as code snippets, theoretical descriptions, and visual representations. Existing examples for mathematical modelling language include GPT-4's Codex. There are remarkable results from Codex in helping write code for mathematical modelling. Bubeck et al. (2023) predict that these technologies will be deeply integrated into educational platforms within the next five years[21].

Today's advances in virtual reality (VR) technology allow us to set up a virtual reality-based modelling laboratory, in which students get to design and manipulate complicated models in a natural, direct manner, thus significantly improving the general learning experience[22]. In the evaluation stage, deep learning based automated evaluators not only rank students' modeling reports but also identify students' logical fallacies in their work, then give feedback based on these. This enables truly personalized learning and individualized learning paths.

4.2 The deep integration of mathematical modeling with AI

Overall, the deep fusion of mathematical modeling and artificial intelligence is having a profound transformation on higher education in terms of teaching goals. There will be a big paradigm shift in the fundamental orientation of the future mathematical modeling education, not only for training students to be masters in multiple tools, but also for building students to become problem architects with a high level of analytic ability. The new breed of talent needs an "AI-supported modeling mindset", i.e., they can take advantage of strong point AI in processing big data, deep comprehension of the context of a problem, and have good interpretability of the model. When carrying real cases, the AI-based interdisciplinary modeling environment provides knowledge support from various fields and helps a student to construct an interdisciplinary complex model for solving real-world complex problems

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quickly [23].

With the increasing application of AI technologies in teaching and learning, the need for ethics education has risen noticeably. Many prestigious colleges and universities have started to include AI ethics in the mathematical modeling course, aiming to make the students possess a steady sense of responsibility to society in the case of using high-tech. For the future, it is necessary to focus on the proportionate incorporation of technology in mathematical modeling teaching with solid background theory learning.

5. Conclusion

As artificial intelligence provides fresh momentum for promoting mathematical modelling abilities among college students, it is significant to strengthen the cultivation of innovative talents by researching and optimizing mathematical modelling education methods for college students. Therefore, this paper studies the way, the difficulty, and the direction of AI technology application in mathematical modelling education in a systematic manner. In line with problems like old-fashioned teaching content and poor interdisciplinary fusion in the conventional teaching and learning of mathematical modeling, we put forward a four-dimensional improvement scheme, namely the optimization of the curriculum system, the cultivation of students' creativity, and the enhancement of practical platform construction, as well as the promotion of teachers' role transformation. By introducing such practices, the existing problems in traditional modeling courses will be alleviated.

Artificial Intelligence as a part of mathematical modelling education is a change not only of tools, but also of the educational paradigm. While this convergence also challenges how we reconsider the pedagogy of the traditional "teaching" and "learning" divide, it must remind us that the fundamental aims of education, which are cultivating the critical consciousness, creativity, and social responsibilities of students, cannot be lost by using technology to replace its effectiveness. In order to make this paradigm shift happen, there needs to be synergy between the educators, the technology providers, and the policymakers to maximally harness the power for talent cultivation with the arrival of the AI era.

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