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Integrating Advanced Mathematics, AI Algorithms, and Intelligent Manufacturing: Development and Teaching Practice of a Digital Training Platform

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Abstract

Because AI, digital technologies and intelligent manufacturing are developing very fast in recent years, higher education now faces increasing demands for interdisciplinary talents who can integrate mathematical knowledge with computational and engineering skills that are important for solving real problems in industrial settings. But advanced mathematics courses are taught separately from AI algorithms. Students cannot see the practical value of mathematical concepts when they learn these theories in class, and they do not know how to use these methods to solve engineering problems in intelligent manufacturing systems. We build an integrated training platform for education and it combines advanced mathematics, AI algorithms and intelligent manufacturing from perspective of digital-intelligent industry-education integration, which means we try to connect theoretical knowledge with real industrial practice in teaching process and help students understand the application background of each mathematical concept they learn. The platform includes calculus, linear algebra, probability, statistics and optimization. These mathematical concepts are connected with AI algorithm training and intelligent manufacturing applications so that students can see how mathematics is used in real systems and understand the relationship between abstract theory and concrete engineering practice. We design a project-based teaching model for this platform that can help students learn through real projects and gain practical experience in solving engineering problems with mathematical methods and AI algorithms in a systematic way that connects different knowledge points together and builds their engineering thinking. It can guide students through complete learning process consisting of mathematical modelling, data processing, algorithm implementation, manufacturing simulation, and result evaluation. We conduct a teaching practice to check if it works and the results show the integrated platform can improve students' understanding of mathematical concepts and help them see the practical meaning of abstract theories in engineering applications that require both mathematical thinking and computational methods to solve complex problems in intelligent manufacturing. Also, it can enhance their ability to apply AI algorithms. It is worth noting that their engineering problem-solving skills are strengthened through practice in the simulation environment that requires students to integrate mathematical methods and AI techniques to handle real manufacturing data and optimize the production process according to practical constraints and engineering standards that are commonly used in industry. Also, the platform provides an interactive learning environment with practice. It promotes the integration of theoretical knowledge with real-world industrial problems that students may encounter in their future careers and helps them build

systematic thinking for solving complex engineering tasks with mathematical and computational tools in a collaborative way that mimics real industrial projects and develops their professional skills. The proposed approach can be used as a reference for interdisciplinary STEM education and the development of digital training platforms in higher education that need to integrate multiple disciplines and build practical teaching systems for training talents in the digital-intelligent era with industry-education integration characteristics.

Keywords

Artificial intelligence; AI algorithms; Intelligent manufacturing; Industry-education integration; Training platform; STEM education.

1. Introduction

Artificial intelligence (AI), big data, Internet of Things and other digital technologies have fast development in recent years and these technologies can transform traditional manufacturing into intelligent systems that use data in production process. Machine learning becomes important. Computer vision can help improve manufacturing processes in modern factory, and predictive analysis is used. Optimization should be considered. In fact, this transformation creates growing demand for graduates who have interdisciplinary knowledge covering mathematics, computing, data analysis and engineering fields at the same time, so universities face new challenges. Therefore, higher education needs to provide more integrated learning environments with practice orientation and it should help prepare students for the requirements of Industry 4.0 which can bring new challenges to education system when we consider the fast development of technology [1], [2].

AI is now important technology for higher education transformation. Some previous works found that AI can support personalized learning and intelligent tutoring. Also, automated assessment and learning analytics can be done with this technology and we can use it for teaching decision-making [3], [4]. Generative AI is a new development and it can expand these possibilities. In fact, it provides students with explanations, programming assistance, feedback, and learning support [5]. But effective use of AI in education depends on availability of technological tools and their integration with specific curricula and authentic learning tasks should be considered, which means we need to think about how to use AI in specific courses and design suitable tasks.

The development of various AI algorithms relies on the core foundations of advanced mathematics, which gives this discipline a crucial role in the field of AI. Derivatives and partial derivatives underpin gradient optimization methods, while machine learning and neural networks require extensive computation involving matrix operations. These mathematical tools are essential for building AI systems and enhancing their performance, and probability theory and statistics support data analysis and intelligent decision-making.But advanced mathematics is taught separately from its applications in AI and engineering. Students can finish the calculations. However, they have difficulty to understand how the mathematical concepts can be transformed into algorithms and applied to practical problems [6-8].

Also, it is worth noting that intelligent manufacturing education now pays more attention to practical training and digital technologies, and interdisciplinary competencies are also expected to be developed. Project-based learning, virtual simulation, digital twins, and other technologies help students interact with realistic industrial scenarios [9-11]. But existing manufacturing training focuses on equipment operation and production processes, also digital tools, and the mathematical principles underlying AI-based manufacturing applications can not always be explicitly integrated into learning process.

From these observations we can see there is a gap in current research. In fact, previous works have studied AI-assisted higher education and AI-supported mathematics education and intelligent manufacturing training is also studied but these areas are examined separately. In existing research, few have focused on building an integrated learning environment that connects mathematical knowledge with AI algorithms and applies these algorithms to various real-world intelligent manufacturing problems. Without such integration, students cannot clearly perceive the concrete connections between theory and practice. This fragmented state makes it difficult for students to understand the practical value of advanced mathematics and to grasp the underlying mathematical mechanisms behind AI-based industrial applications.

Current training methods have limitations. This paper develops a comprehensive training platform based on digital-intelligent integration of industry and education, which theoretically combines advanced mathematics with AI algorithms and incorporates intelligent manufacturing technologies, enabling students to gain a holistic understanding of the entire system. The paper establishes a learning pathway that extends from mathematical concepts to AI algorithms and further to manufacturing applications. Students can follow this path to study derivatives and optimization, explore their practical roles in AI model training, and apply relevant algorithms to equipment condition prediction, product quality inspection, and production parameter optimization.

The following are the main contributions of this paper:

1. The comprehensive training platform developed in this study integrates three content areas—advanced mathematics, AI algorithms, and intelligent manufacturing—into a unified learning environment.

2. This paper proposes a project-centric teaching framework to advance the transformation of mathematical knowledge into algorithm implementation and engineering applications.

3. This paper presents a teaching practice that evaluates the proposed method by focusing on students' mathematical understanding, AI application skills, and engineering problem-solving abilities.2. Related Work

1.1. Artificial Intelligence in Higher Education

Over the past decade, the application of artificial intelligence (AI) in higher education has advanced rapidly, with numerous universities integrating intelligent systems into their teaching management processes to enhance overall operational efficiency. Early research focused on areas such as intelligent tutoring systems, adaptive learning, automated assessment, and student performance prediction. Subsequent studies have shifted toward generative AI, learning analytics, personalized learning, and AI-assisted instructional design—directions that empower university educators to develop higher-quality course content and optimize the learning experience for students at the higher education level.

Crompton and Burke[3]Between 2016 and 2022, a review and analysis of AI research in higher education revealed that teaching and learning constitute the core areas where AI technologies can be practically deployed, offering support within the daily learning processes of both students and educators.AI can give personalized support to the students. Their results also show this technology can improve the efficiency of educational processes, but the review shows that AI applications are distributed across diverse educational contexts and this makes it hard to achieve consistent outcomes in different courses. In fact, effectiveness of the AI can depend on course characteristics and pedagogical design.

Bond et al. [4] examined previous reviews. They conducted meta-systematic review and analyzed 66 publications about AI in higher education. Their results indicate that adaptive systems and personalization are main research areas, and they also call for greater methodological rigor, ethical consideration, contextualization, and interdisciplinary collaboration. This observation can be relevant to interdisciplinary courses. In fact, an

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educational AI system should provide technical functionality and it should support learning objectives and knowledge structure of a specific discipline.

Recently, generative AI brings a new research direction. Ogunleye et al. [5] examined 355 studies from an initial set of 625 publications, and they found that interest in generative AI for teaching and learning is increasing. Existing research suggests that future studies on AI should move beyond general discussions and instead focus specifically on curriculum integration, instructional assessment, instructional design, and interdisciplinary applications to clarify practical pathways for AI implementation in education. This paper does not aim to replace teachers or mathematical reasoning processes with AI; rather, it seeks to integrate AI-related technologies into structured curricula and practical training environments.

1.2. AI-Assisted Mathematics Education

Mathematics learning typically requires personalized instruction, repeated practice, immediate feedback, and adaptive difficulty settings—needs that make math education a key application area for AI technology.

Panqueban and Huincahue[6] Regarding the application of artificial intelligence in mathematics education, relevant research has been completed. The findings indicate that AI technology can be applied in various areas such as personalized learning, academic assessment, teaching assistance, and learning data analysis. It can also optimize the interaction between students and mathematics learning resources. However, most current applications treat mathematics solely as a target subject for study, without recognizing it as a foundational knowledge system that supports other technical disciplines.

Yoon and Kwon[7] This study analyzes research on AI-assisted mathematics instruction, focusing on clarifying the distinct roles of AI and teachers within educational contexts, as well as exploring their collaborative approaches in authentic classroom settings. The findings indicate that while AI can support a wide range of teaching activities, teacher involvement remains indispensable. Teachers are responsible for interpreting the learning process, designing instructional activities, and ensuring teaching quality; consequently, AI cannot fully replace teachers within the current educational system. These conclusions provide a foundation for the human-machine collaboration principles adopted in this paper: teachers define learning objectives, design instructional tasks, and interpret outcomes, while AI tools handle computational tasks and offer learning support.

Intelligent tutoring systems are also an important direction. In fact, Son [8] examined the intelligent tutoring systems used in mathematics education and analyzed how these systems develop from perspective of the Substitution, Augmentation, Modification, and Redefinition framework, which can help us understand the technology integration levels. These systems can give individual learning support and feedback. However, these systems focus on improving students' mathematical learning experiences and they do not pay attention to connecting mathematical knowledge with AI algorithms and industrial applications.

Existing studies show that AI can have good potential for mathematics education. But one more step should be taken. In fact, students should understand how mathematical concepts become computational mechanisms in the AI algorithms and these algorithms can then be used to solve engineering problems in real world.

1.3. Education 4.0 and Interdisciplinary STEM Learning

Education 4.0 focuses on integration of emerging technologies, flexible learning environments, industry-oriented competencies, and student-centered pedagogies. Rienties et al. [1] examined the Education 4.0 practices in higher education and computer science and they found project-based learning and hands-on learning are important approaches we can use to connect education with technological development. In fact, these methods are widely used.

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Mukul and Büyüközkan [2] examined the Education 4.0 in full review. They showed that digital technologies and new learning methods are important for schools because Industry 4.0 brings many changes that education systems must adapt to quickly in order to stay relevant. Also, new educational environments can help. In fact, their findings indicate that educational transformation involves more than introducing new technologies. It also requires changes in curriculum organization and teaching methods and we should consider competency development because these factors together can determine whether the transformation is successful in practice.

Aboderin and Havenga [9] examined key skills and teaching strategies required in the higher education for the Fourth Industrial Revolution and we can learn from their findings. It is worth noting that we can see from their systematic review that critical thinking and complex problem solving, also teamwork, active learning and self-directed learning, can be important competencies. Also, these are consistent with objectives of project-based interdisciplinary training.

In fact, Education 4.0 research gives the theoretical basis for our study, so we can use these results as a reference.But most existing research discusses technology integration and competency development at relatively broad level and they do not consider the specific technical details and how these integration methods can be used in actual teaching scenarios when we face different practical constraints from the real industrial environment.The specific integration of mathematical foundations and AI algorithmic thinking with intelligent manufacturing tasks is unclear.

1.4. Intelligent Manufacturing and Practical Engineering Education

Industry 4.0 has changed the skills required by the manufacturing professionals. Students should understand traditional engineering principles. Also, they need to learn data analytics, automation, AI, and other digital technologies, because interdisciplinary problem solving is now essential for the modern production systems and can help improve the overall efficiency when the students enter the manufacturing industry after graduation. Previous studies show that Industry 4.0-related competencies are becoming more important [10]. In fact, stronger cooperation among universities, enterprises, and learning factories can support this trend.

Practical education can be important in this field. In fact, Motyl and Filippi [12] examined engineering education related to additive manufacturing in Industry 4.0 era and they found that when students have exposure to these emerging manufacturing technologies, this experience can help them develop necessary engineering competencies. But they also noted some challenges and equipment availability is limited and teacher expertise may not be sufficient.

Recently, digital twin technologies provide new chance for manufacturing education. Szántó et al. [11] built educational platform using digital twins, IoT and also cyber-physical systems. They show that digital manufacturing environments can give realistic training scenarios and support learning-by-doing. In fact, digital twin-based approaches can reduce dependence on physical equipment. They can give flexible environments for repeated experimentation.

Recent years have seen many advances. But in current manufacturing education platforms, we focus on manufacturing processes, digital simulation, equipment operation, and specific Industry 4.0 technologies.The mathematical foundations of AI algorithms can be seen as background knowledge. Also, they are not treated as main part in the practical learning process, and this can make it hard for students to understand the algorithms.

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2. Platform Development and Teaching Practice

2.1. Platform Development

It is worth noting that we developed practical training platform which can connect advanced mathematics with AI algorithms and intelligent manufacturing, and it can be used for student training. Fig. 1 shows the platform is designed based on a simple learning pathway which can help students understand the whole process, and it includes the following steps: mathematical knowledge → AI algorithms → intelligent manufacturing applications.

The platform has three main parts. In first part, we provide mathematics learning resources covering calculus, derivatives, matrices, probability and statistics. It is worth noting that optimization methods are included here so that users can build a solid mathematical foundation for their later study. The second part is designed for basic AI algorithm training. Users can do data processing and model training and the system supports result analysis. The third part shows intelligent manufacturing cases and equipment condition prediction and product quality inspection are included here and production parameter optimization can be found in this module which can help users understand real applications and solve practical problems in manufacturing environment so they can learn how to apply AI in real factories.

This article does not replace traditional classroom teaching; instead, it establishes practical scenarios on the platform where students apply mathematical knowledge to AI algorithm development and then address real-world manufacturing challenges. This approach clarifies the connection between mathematical theory and industrial applications, helping students better understand the relationship between mathematical theory and emerging technologies.

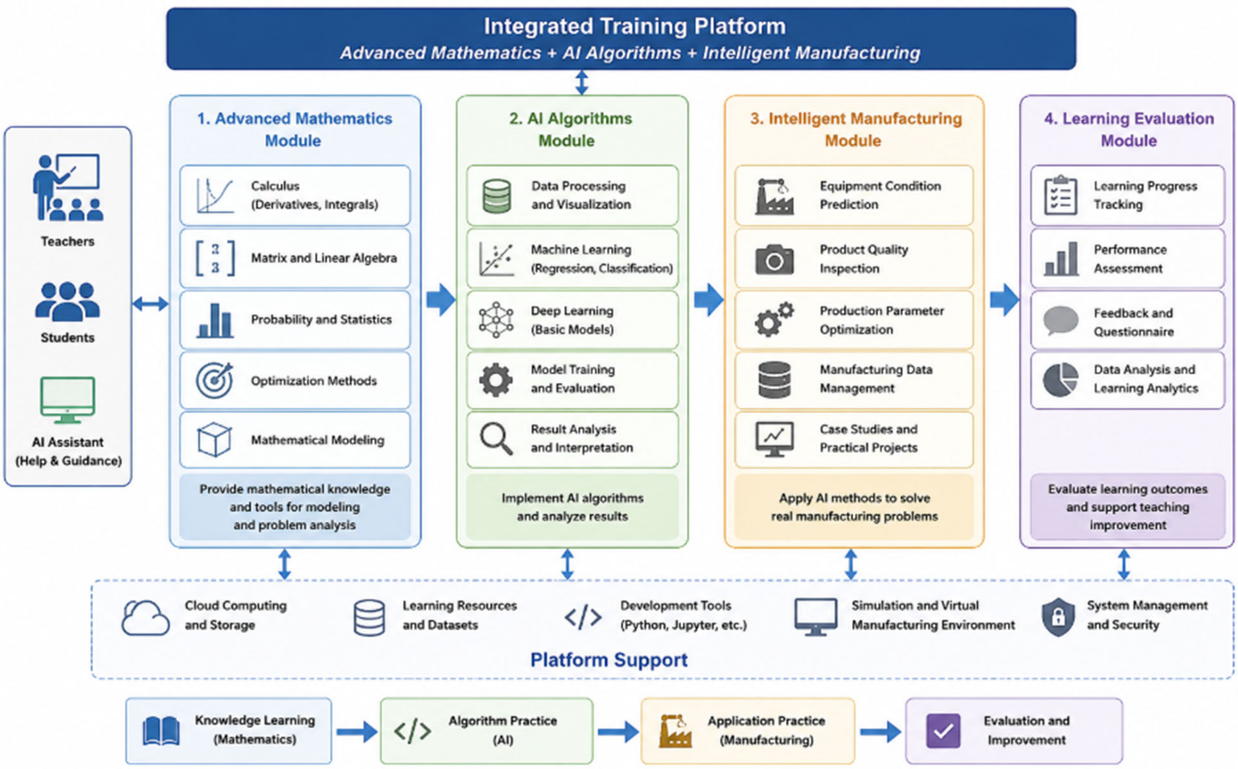

Figure 1. Overall structure of the integrated training platform.

This article can integrate online learning resources and Python-based computational resources to complete the setup of this platform.Hands-on training involves tools, manufacturing domain datasets, and physical training equipment, with the configuration of physical devices

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determined based on available resources.Virtual simulation technology can be combined with other technologies to provide flexible implementation conditions for training.

2.2. Teaching Design

This paper relies on this platform to implement project-based teaching mode, abandoning the traditional teaching method that simply introduces mathematics content.During the course of teaching, the teacher does not directly explain the formula, but first throws out a practical problem related to intelligent manufacturing.As a practical example, when performing a task to predict the condition of a device, the staff will provide the participating students with basic device data, such as Various parameters including temperature, vibration, current and operating time were included. After observing the corresponding data, the students participating in the experiment explored possible related directions.This article mentions the correlation between different variables, and then the teaching teacher explains related mathematical concepts, such as Statistics, Functions, and Optimization.Students first understood the mathematical concepts, then used Python and basic AI algorithms to process the data.Complete the construction of a predictive model. During the construction of the model, guide students to understand the mathematical principles Focus on exploring the underlying logic of the algorithm and avoid directly using off-the-shelf code.

Finally, the students involved in the experiment applied the model to specific cases in the field of manufacturing. After analyzing the results, they began to discuss whether the research needs were met .This paper identifies the factors that may affect the performance of the model, and the resulting predictions are reasonable.

This paper identifies the factors that may affect the performance of the model, and the resulting predictions are reasonable.In Fig. 2, the teaching process can be summarized as: Practical Problem → Mathematical Analysis → AI Algorithm → Manufacturing Application → Result Analysis. This process can give students connection between theory and practice, and it can help them understand the manufacturing context.

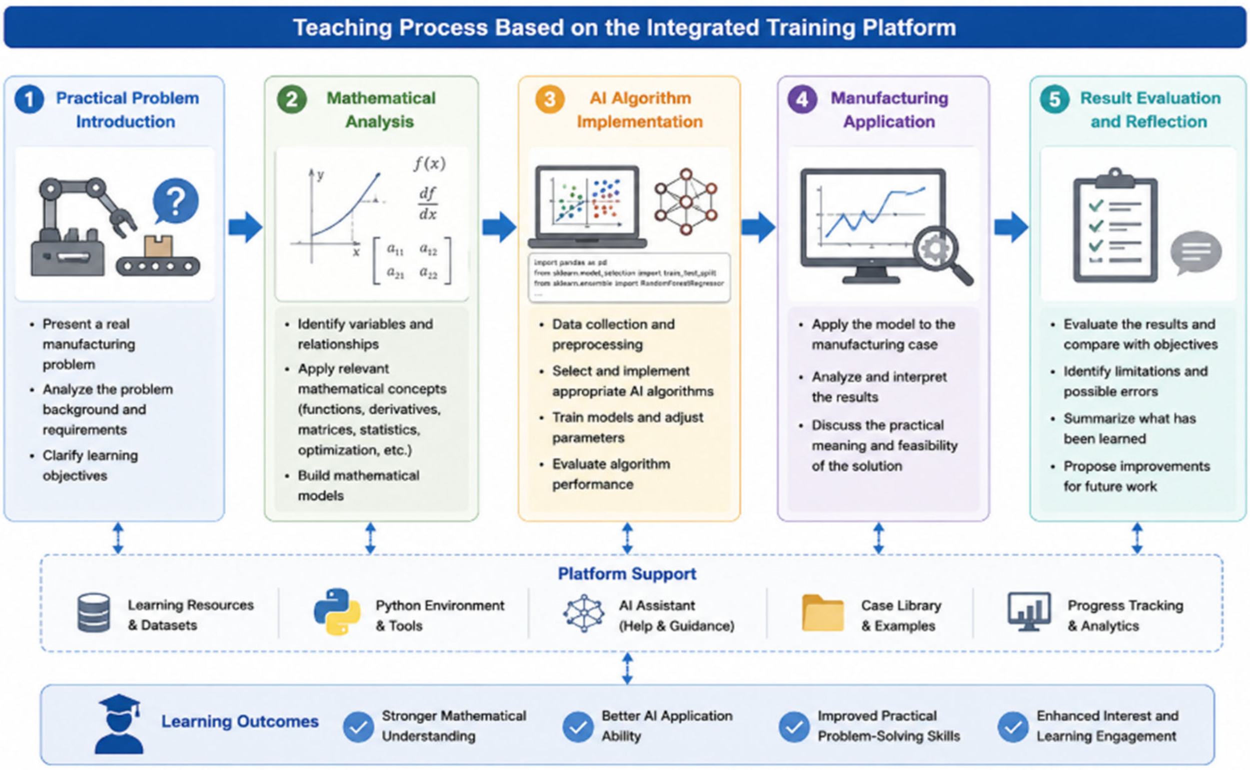

Figure 2. Teaching process based on the integrated training platform.

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2.3. Teaching Practice

The proposed platform was applied in a practical teaching activity focusing on intelligent equipment condition prediction. As shown in Fig. 3, students worked in small groups and completed the training task through several basic steps.

In first step, we analyze the manufacturing dataset. It is worth noting that the main variables can be found from this data and they are expected to be used in following analysis.Then mathematical methods are used. We can describe the data and investigate relationships among the variables, which can help us understand the manufacturing process.Next, we implement a simple AI prediction model with Python. This model should work for the equipment condition prediction in principle and it can avoid complex manual calculation.Finally, we apply the model to the equipment condition prediction task. We analyze results.

During the practical activity, the teacher provided guidance when students encountered difficulties in mathematical analysis, programming, or model interpretation. AI-based tools were also allowed as supplementary learning resources for explaining concepts, checking code, and identifying programming errors. However, students were required to explain their solutions and interpret the results independently.

Figure 3. Students participating in the practical training activity.

In teaching practice, we found integrated approach can give students direct understanding. It is about the relationship between mathematics and AI algorithms, also intelligent manufacturing. In fact, students do not learn these in separate way and they can see how mathematical knowledge is used in algorithm development, also they can see how the resulting algorithms can be applied to practical manufacturing problems.

When integrating theoretical learning with practical work, this platform can be utilized to adopt a relatively simple and flexible approach, combined with hands-on training to advance application. This method can be extended to more scenarios, such as product quality inspection and production data-related processes. This paper completes the analysis work and promotes process parameter optimization.

3. Evaluation

3.1. Evaluation Method

This article conducts a teaching evaluation to verify the effectiveness of the proposed comprehensive training platform.In conducting this evaluation, we considered students'

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academic performance and their feedback, focusing on three specific assessment areas, which include content related to mathematics.The three core competencies mentioned in this article are: the ability to understand professional-related content, the capability to apply artificial intelligence technologies, and the skill to solve practical problems.

Before and after the practical training, the participating students have completed their learning tasks, and relevant personnel have conducted evaluations of their performance.This paper incorporates mathematical exercises and AI algorithm tasks when carrying out relevant assignments, alongside a comprehensive manufacturing project, and additionally includes a brief section.The author used a questionnaire format to collect various opinions from students regarding their learning experiences.

The questionnaire used a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The main questions focused on whether the platform helped students understand mathematical concepts, understand AI algorithms, connect theoretical knowledge with practical problems, and improve their learning interest.

We selected this evaluation method and it is worth noting that study has two goals. One is to examine students' final scores. Also, we should check whether integrated platform can help students connect knowledge from different disciplines.

3.2. Learning Results

The teaching practice showed positive changes in students' learning performance. After participating in the integrated training activities, students generally demonstrated better understanding of mathematical concepts and greater ability to apply these concepts in AI-related tasks.

For mathematical learning, students showed improved ability to connect concepts such as derivatives, statistics, and optimization with practical problems. Instead of treating mathematical formulas as isolated knowledge, students were able to identify their applications in data analysis and AI model training.

For AI algorithm learning, students demonstrated a better understanding of the basic process of data preprocessing, model training, and result evaluation. The practical tasks also helped students understand the relationship between mathematical principles and algorithm performance.

For practical problem solving, students were required to apply the learned knowledge to an intelligent manufacturing problem. This process encouraged them to analyze the problem, select appropriate methods, implement the solution, and interpret the results. Compared with completing independent mathematical or programming exercises, the integrated task required students to use knowledge from several areas simultaneously. The main learning outcomes can be summarized in Table 1.

Table 1. Comparison of students' learning performance before and after the training

Evaluation Item	Pre-training	Post-training	Improvement	Improvement (%)
Mathematical understanding	64	83	+19	+29.7%
AI algorithm application	58	81	+23	+39.7%
Practical problem solving	60	79	+19	+31.7%
Overall performance	61	81	+20	+32.8%

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Questionnaire results can indicate a positive learning experience. Most students reported that practical tasks can help them understand the relationship between advanced mathematics and AI algorithms and this is good for their learning. In fact, students show positive attitude toward using manufacturing cases as learning context.

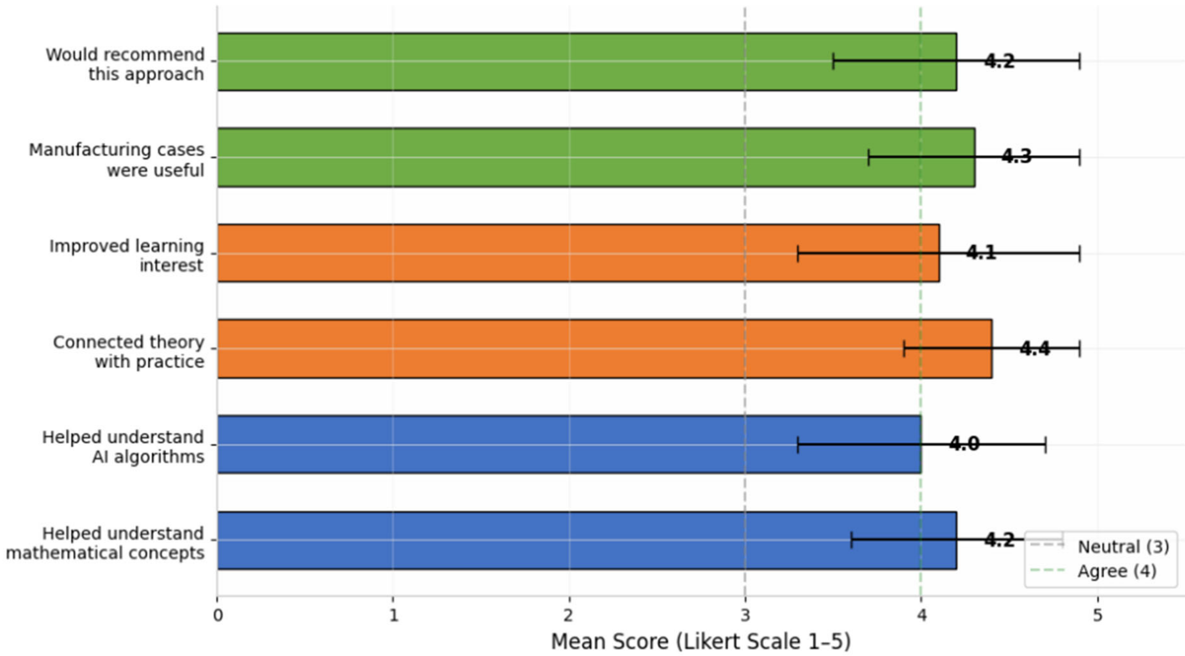

Figure 4. Student feedback on the integrated training approach.

The results suggest that the proposed platform can provide students with a more application-oriented learning environment. In particular, connecting mathematical concepts with AI algorithms appears to reduce the distance between theoretical learning and practical applications.

4. Conclusion

We developed an integrated training platform for digital-intelligent industry-education integration. It includes advanced mathematics and AI algorithms, and we also consider intelligent manufacturing. The platform can establish a learning pathway from basic mathematical concepts and computational methods to practical manufacturing applications in real industrial environment and it should help students build a full understanding of the whole process from theory to practice which is very important for their future work. In fact, we connect theoretical knowledge with AI-based tasks and industrial cases. Then students can understand how mathematical principles can be used to support intelligent technologies and solve practical problems.

The teaching practice demonstrated the potential value of the proposed approach in interdisciplinary education. Through project-based activities, students were guided to analyze practical problems, apply relevant mathematical knowledge, implement basic AI algorithms, and interpret the results in manufacturing contexts. This process can help students better understand the practical meaning of advanced mathematics, improve their ability to apply AI algorithms, and strengthen their problem-solving and practical skills. The platform also provides a more interactive and application-oriented learning environment compared with traditional teaching based mainly on theoretical explanations and exercises.

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There are still some limitations to this study. The current teaching practice was conducted within a relatively limited educational context, and the number of participants and practical cases was limited. Therefore, further research is needed to evaluate the effectiveness of the platform on a larger scale and over a longer period. Future work will focus on expanding the platform with more AI algorithms, manufacturing scenarios, and interactive functions, while introducing more systematic evaluation methods. Overall, this study provides a practical reference for integrating mathematics education, AI technology, and intelligent manufacturing training, and offers a feasible approach for interdisciplinary talent development in the context of Industry 4.0. This study developed an integrated training platform that combines advanced mathematics, AI algorithms, and intelligent manufacturing. The platform connects theoretical knowledge with practical applications and provides students with a clear learning process from mathematical concepts to AI algorithms and manufacturing problems.

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