Exploration of Education for Vocational College students under the Integrated Mode of Science and Education in the Course of 3D Printing Technology

Jinyan Liu[a]*, Qing Li[b], Yuan Gao[c]

Guangdong Mechanical and Electrical Polytechnic, Guangzhou, China

`[a]liujinyan21@163.com, [b]471312769@qq.com,`
`[c]gaoyuan315@163.com`

Abstract. In the contemporary era marked by rapid technological advancements, 3D printing technology has emerged as a powerful tool in various industrial applications. This paper explores the integration of 3D printing into STEM education under the integrated mode of science and education, aiming to cultivate high-skilled talents adapted to new productivity paradigms. Through a combination of field experiments, case studies, and surveys conducted at multiple technical institutions, the practical pathways for embedding 3D printing technology into the curriculum were investigated. This study involves detailed evaluations of 3D printing parameters, material selection, and application-specific techniques, assessing their effectiveness in enhancing technical competencies and innovative capacities among students. The data collected from 100 participants across educational settings integrated 3D printing science project and nonintegrated was analyze, highlighting the benefits and challenges associated with this technological integration. The findings suggest a significant improvement in student engagement and skill acquisition, reinforcing the value of incorporating emerging technologies into educational frameworks. The theoretical foundations, methodological approaches, and practical implications of this integration were discussed, offering insights and recommendations for future educational practices and policy formulation.

Keywords: Integrated Mode of Science and Education, 3D Printing, vocational education

1 Introduction

The origins of 3D printing technology can be traced back to the 1980s. It is a technology processing layer by layer to create three-dimensional objects [1], including Stereolithography (SLA), fused deposition modeling (FDM), selective laser sintering (SLS), direct metal laser sintering (DMLS), and so on [2]. As these technologies matured and became more accessible, their potential applications in education began to gain recognition.

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The integration of 3D printing science project in educational settings has been shown to offer numerous benefits, particularly in the fields of science, technology and engineering [3]. Some ability including problem-solving ability, and creativity can be enhanced by 3D printing science program training through providing students with hands-on experience in designing, modeling, and fabricating physical objects [4]. Moreover, 3D printing provide an approach through which students can rapidly prototype, test, and refine their designs [5]. This approach aligns with constructionist learning theories, which emphasize the importance of actively constructing knowledge system through the creation of tangible artifacts [6].

Several case studies have demonstrated the successful implementation of 3D printing science project in educational institutions across various levels. At the K-12 level, schools have incorporated 3D printing into their curricula to engage students in project-based learning and foster interest in STEM subjects [7]. A study conducted by Johnson et al. [8] found that the use of 3D printing in a middle school science class significantly improved students' understanding of complex scientific concepts and increased their motivation to pursue STEM careers. Similarly, in higher education, universities have established dedicated 3D printing labs and integrated the technology into engineering, design, and medical programs [9]. A notable example is the University of Michigan's "3D Lab," which provides students and faculty with access to advanced 3D printing equipment and expertise, facilitating interdisciplinary research and innovation [10].

The adoption of 3D printing science project in education has also been driven by the recognition that the technology. It is transforming traditional manufacturing processes and creating new opportunities for innovation and entrepreneurship [11]. Because industries increasingly embrace additive manufacturing, there is a growing demand for professionals with the skills and knowledge necessary to leverage these technologies effectively [12].

In the context of 3D printing science project, the high-skilled talent-training requires a multifaceted approach that encompasses curriculum design, practical training, and industry collaboration. Firstly, educational institutions must identify the specific skills and knowledge areas that are essential for proficiency in additive manufacturing, such as 3D modeling, material science, and process optimization [13]. These competencies should be integrated into existing STEM curricula with an emphasis on project-based learning and hands-on experience [14]. Additionally, the assessment of skill level should be different from traditional methods and incorporate performance-based evaluations that assess students' ability to apply their knowledge in real-world scenarios [15]. Secondly, practical training programs, such as internships and apprenticeships, play a crucial role in bridging the gap between theoretical knowledge and industry application [16]. By partnering with 3D printing companies and technologies, educational institutions can provide students with opportunities to gain practical experience in real-world settings. This can expose students to the challenges and practices of the industry [17]. These collaborations also facilitate knowledge transfer between academia and industry to meet the needs of the workforce [18]. Thirdly, the successful integration of 3D printing science project in education requires the adoption of effective technology integration strategies. This not only requires investment in material and human resources, but also in supporting infrastructure, including technical support, maintenance, and training for educators [19]. Furthermore, the implementation of 3D printing science project should be accompanied by a change of pedagogical approaches from traditional lecture-based instruction to more student-centered, inquiry-based learning models [20].

Despite the benefits of integrating 3D printing project in education, several challenges must be addressed to ensure its successful implementation. One of the primary barriers is the cost associated with acquiring and maintaining 3D printing equipment, which can be prohibitive for many educational institutions [21]. To overcome this challenge, schools and universities can explore partnerships with industry sponsors, seek grant funding, or establish shared resources through consortia or regional networks [22]. In addition, the integration of 3D printing science project in education raises various policy and regulatory issues, such as intellectual property rights, safety concerns, and ethical considerations [23-29].

In conclusion, the integration of 3D printing science project in education holds immense potential for developing high-skilled talent capable of thriving in the era of digital fabrication. By providing students with hands-on experience, fostering collaboration with industry partners, and adopting effective technology integration strategies, educational institutions can equip learners with the skills and knowledge necessary to succeed in the rapidly evolving landscape of additive manufacturing. However, realizing this potential requires a concerted effort to address the challenges associated with cost, curriculum development, and policy issues. Through collaboration among stakeholders in education, industry, and government, it is possible to create a supportive ecosystem that nurtures innovation, creativity, and the development of a highly skilled workforce ready to meet the demands of the future [30].

2 Developing High-Skilled Talent

2.1 Skills Required for New Quality Productive Forces

Modern manufacturing necessitates a new set of skills among the workforce to adapt to these evolving production processes [31]. As 3D printing becomes increasingly integrated into various industries, it is crucial to cultivate skilled professionals in 3D printing technology. A comprehensive understanding of the skills for new quality productive forces is necessary to design curricula that adequately prepare individuals for the demands of the 3D printing industry.

One of the primary skills essential for success in 3D printing is proficiency in computer-aided design (CAD) software. CAD software, such as AutoCAD, SolidWorks, and NX, plays a vital role in the creation of 3D models that serve as the foundation for the printing process. Individuals must possess a strong understanding of 3D modeling techniques, including the ability to create, manipulate, and optimize digital models for printing. Proficiency in CAD software enables individuals to design complex geometries, assess the feasibility of designs for printing, and make necessary adjustments to ensure perfect 3D model output [32].

In addition to CAD proficiency, it is crucial to know 3D printing materials and their properties for optimizing the printing process and achieving desired outcomes. Many different materials with unique characteristics, including plastics, metals, ceramics, and composites are used in 3D printing field. Therefore, it is essential to understand the mechanical, thermal, and chemical properties of these materials for selecting the appropriate material. This knowledge also enables individuals to troubleshoot issues related to material performance, such as warping, shrinkage, or poor layer adhesion, and make informed decisions regarding post-processing techniques, such as sanding, painting, or heat treatment [33].

Another critical skill set is an understanding of 3D printer operation and maintenance. As 3D printers become more sophisticated and varied in their capabilities, individuals must possess the knowledge and skills to effectively operate and maintain these machines. This includes an understanding of the various components of a 3D printer, such as the extruder, build platform, and motion system, as well as the ability to calibrate and fine-tune these components for optimal performance. Regular maintenance tasks, such as cleaning, lubricating, and replacing worn parts, are essential for ensuring the longevity and reliability of 3D printers. Individuals with a strong grasp of printer operation and maintenance can minimize downtime, reduce waste, and consistently produce high-quality prints [34].

Problem-solving and critical thinking skills are also paramount in the realm of 3D printing. The additive manufacturing process often involves complex geometries, intricate designs, and unique material combinations, which can lead to various challenges and obstacles. Individuals must possess the ability to analyze problems, identify root causes, and develop innovative solutions to overcome these hurdles. This may involve adjusting design parameters, modifying printer settings, or experimenting with alternative materials or post-processing techniques. Strong problem-solving skills enable individuals to adapt to the ever-evolving nature of 3D printing technology and find creative solutions to complex manufacturing challenges [35].

Finally, collaboration and communication are essential skills for success in the 3D printing industry. 3D printing projects often involve multidisciplinary teams, including designers, engineers, material scientists, and manufacturing specialists. Effective collaboration and communication among these team members are crucial for ensuring project success and achieving desired outcomes. Individuals must possess the ability to articulate ideas clearly, provide constructive feedback, and work collaboratively to resolve conflicts and make informed decisions. Strong interpersonal skills also facilitate knowledge sharing and continuous learning, enabling individuals to stay up-to-date with the latest advancements in 3D printing technology and best practices [16].

In conclusion, the skills required for new production paradigms in the era of 3D printing are diverse and multifaceted. Proficiency in CAD software, knowledge of 3D printing materials, understanding of printer operation and maintenance, problem-solving and critical thinking abilities, and strong collaboration and communication skills are all essential for success in this field. As educational institutions and training programs strive to develop high-skilled talent for the 3D printing industry, it is crucial to design curricula that effectively address these skill sets. By providing comprehensive training and hands-on experience in these areas, it can ensure that the workforce is well-prepared to adapt to the evolving demands of 3D printing technology and contribute to the advancement of modern manufacturing practices.

2.2 Curriculum Design and Implementation

A comprehensive curriculum system should be established based on the requirements and the curriculum design principles of integrating 3D printing science project into education to cultivate high-skilled talents. The curriculum design should focus on the interdisciplinary integration of 3D printing science project with various fields, such as mechanical engineering, materials science, computer science, and industrial design, to reinforce STEM education [17]. The curriculum should cover the fundamental theories, key technologies, and practical applications of 3D printing, with an emphasis on hands-on experience and project-based learning.

Both theoretical courses and practical training modules should be included in the curriculum design. The theoretical courses should provide students with a solid foundation in the principles and concepts of 3D printing technology, including 3D modeling, slicing algorithms, material properties, and post-processing techniques. These courses should be designed to develop students' critical thinking and problem-solving skills, as well as their ability to apply theoretical knowledge to real-world scenarios [18].

Practical training modules should be an integral part of the curriculum. Students can gain hands-on experience with 3D printing equipment and software. These modules should be designed to develop students' technical skills, such as 3D modeling, printer operation, and troubleshooting. Project-based learning should be incorporated into the practical training modules. Project-based learning requires students to work collaboratively on real-world projects that involve the design, prototyping, and fabrication of 3D printed objects [19].

To ensure the effectiveness of the curriculum, it is essential to establish a robust assessment system that evaluates students' knowledge acquisition, skill development, and practical application abilities. The assessment system should include both formative and summative assessments, such as quizzes, assignments, projects, and exams. The assessment criteria should be aligned with the learning objectives and industry standards, to ensure that students are well-prepared for the demands of the new quality productive forces [20].

Furthermore, the curriculum should be designed to foster students' creativity, innovation, and entrepreneurial spirit. This can be achieved by incorporating design thinking, problem-based learning, and entrepreneurship education into the curriculum. Students should be encouraged to develop their own ideas and solutions to real-world problems using 3D printing technology, and to explore the commercial potential of their innovations [21].

To support the implementation of the curriculum, it is crucial to establish a well-equipped 3D printing lab with state-of-the-art equipment and software. The lab should be accessible to students for both coursework and extracurricular activities, providing them with ample opportunities to practice their skills and explore new ideas. Additionally, faculty members should receive professional development training to ensure that they are well-versed in the latest 3D printing technologies and pedagogical approaches [22].

Collaboration with industry partners is another essential aspect of curriculum implementation. Industry partners can provide valuable insights into the current and future needs of the job market, as well as offer internship and employment opportunities for students. They can also contribute to the development of the curriculum by providing case studies, guest lectures, and mentorship programs [23].

In summary, the curriculum design and implementation for integrating 3D printing technology into education to cultivate high-skilled talents should be comprehensive, interdisciplinary, and practice-oriented. It should cover both theoretical foundations and practical applications, with a strong emphasis on hands-on experience and project-based learning. The curriculum should be supported by a robust assessment system, well-equipped facilities, and industry collaborations. By implementing such a curriculum, educational institutions can effectively prepare students for the new production paradigms and contribute to the development of a highly skilled workforce.

2.3 Assessment of Skill Acquisition

To effectively assess the acquisition of high-skilled talent in the context of 3D printing integration in education, a comprehensive evaluation framework must be established. This framework should encompass a range of assessment methodologies that can effectively measure learners' mastery of theoretical knowledge, practical skills, and problem-solving abilities, aligned with STEM education goals [24]. A multi-dimensional approach to assessment is critical to ensure that learners have developed the necessary competencies to thrive in the new production paradigms enabled by 3D printing technology.

One key component of the assessment framework should be the development of standardized tests that can evaluate learners' understanding of the fundamental principles and concepts underlying 3D printing technology. These tests should be designed to assess learners' knowledge of 3D printing processes, materials, software, and hardware, as well as their ability to apply this knowledge to real-world scenarios. The tests should be psychometrically validated to ensure their reliability and validity in measuring learners' knowledge acquisition [25].

In addition to standardized tests, performance-based assessments should be incorporated into the evaluation framework to assess learners' practical skills in using 3D printing technology. These assessments can take the form of hands-on projects, where learners are required to design, model, and print 3D objects based on specific requirements and constraints. The assessment criteria should be clearly defined, focusing on aspects such as design quality, dimensional accuracy, material selection, and print quality. Rubrics can be developed to provide a structured approach to evaluating learners' performance, ensuring consistency and fairness in the assessment process [26].

To assess learners' problem-solving abilities, case study-based assessments can be employed. These assessments present learners with real-world challenges related to 3D printing, such as optimizing print settings for complex geometries, troubleshooting print failures, or selecting appropriate materials for specific applications. Learners are required to analyze the problem, identify potential solutions, and justify their approach based on their understanding of 3D printing principles and best practices. These assessments can be evaluated using a combination of rubrics and expert review, ensuring that learners' problem-solving skills are assessed holistically [27].

Furthermore, portfolio-based assessments can be used to provide a comprehensive view of learners' skill acquisition over time. Learners can be required to maintain a digital portfolio that showcases their 3D printing projects, design iterations, and reflections on their learning process. This portfolio can serve as evidence of learners' growth and development, demonstrating their ability to apply 3D printing knowledge and skills in various contexts. Portfolios can be evaluated using predefined criteria that align with the learning objectives of the curriculum, providing a structured approach to assessing learners' overall competence [28].

To ensure the validity and reliability of the assessment process, it is crucial to involve multiple stakeholders, including educators, industry experts, and assessment specialists. Educators can provide insights into learners' progress and performance in the classroom setting, while industry experts can offer valuable perspectives on the relevance and applicability of the assessed skills in real-world contexts. Assessment specialists can help in designing and validating the assessment instruments, ensuring that they meet the necessary psychometric standards [29].

Regular formative assessments should be conducted throughout the learning process to provide learners with timely feedback and support their continuous improvement. These assessments can take the form of quizzes, peer evaluations, or self-assessments, allowing learners to monitor their own progress and identify areas for further development. Formative assessments can also inform instructional decisions, enabling educators to adapt their teaching strategies to meet the diverse needs of learners [30].

To measure the long-term impact of 3D printing education on learners' career readiness and success, longitudinal studies can be conducted. These studies can track learners' employment outcomes, job performance, and career progression over time, providing valuable insights into the effectiveness of the educational program in preparing learners for the demands of the workforce. Data collected through these studies can be used to refine the curriculum and assessment framework, ensuring that they remain aligned with the evolving needs of the industry [31].

In conclusion, assessing the acquisition of high-skilled talent in the context of 3D printing integration in education requires a comprehensive and multi-dimensional approach. By combining standardized tests, performance-based assessments, case study-based assessments, and portfolio-based assessments, educators can obtain a holistic view of learners' knowledge, skills, and problem-solving abilities. The involvement of multiple stakeholders, regular formative assessments, and longitudinal studies can further enhance the validity and reliability of the assessment process. By implementing a robust assessment framework, educational institutions can ensure that learners are well-prepared to meet the demands of the new production paradigms enabled by 3D printing technology, contributing to the development of a highly skilled workforce that can drive innovation and economic growth.

3 Practice Path and Methods

3.1 Practical Training Programs

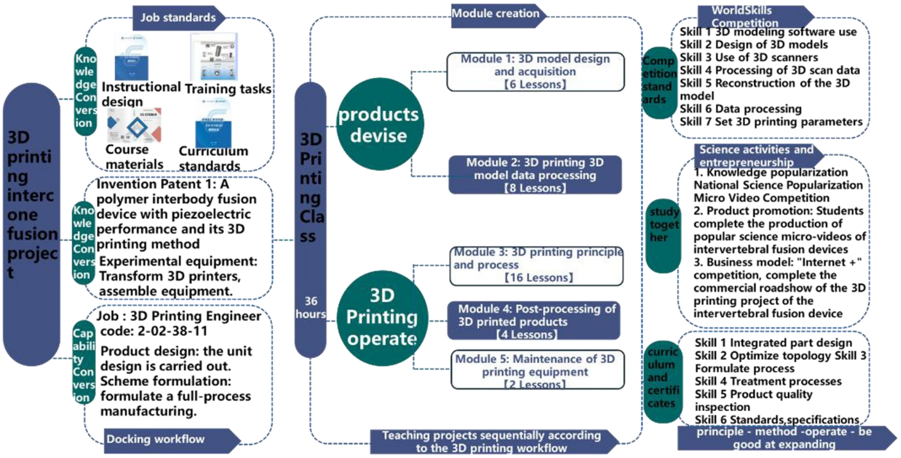

Fig. 1. Integration of 3D printing science projects and 3D printing class

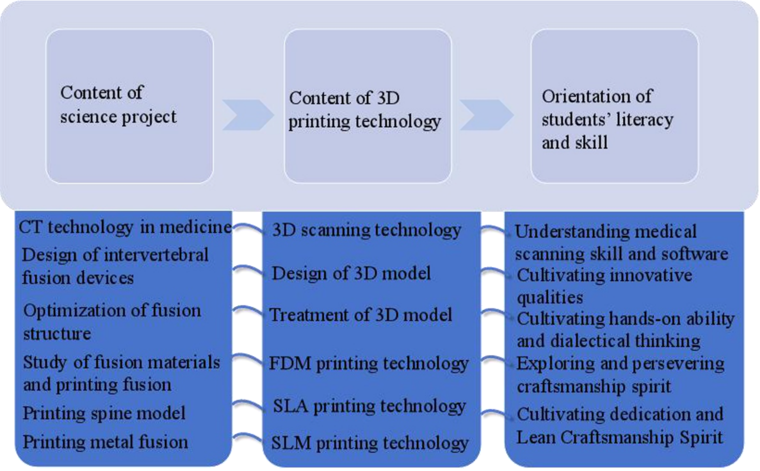

Fig. 2. Integration of course theoretical knowledge and 3D printing science projects

Practical training programs are a critical component in integrating science training into 3D printing technology curricula to cultivate high-skilled talent. In this study, a science project about “Research and development of key technologies for biomedical piezoelectric composite materials based on 3D printed intervertebral fusion devices” (fund number: 2024B03J1242) was integrated in the 3D printing technology course. This science project encompasses various aspects, including 3D modeling of intervertebral fusion devices, slicing software, raw material manufacturing of FDM, printer operation, post-processing techniques, and troubleshooting, and biological experiment. As shown in Figure 1, the integration of the 3D printing science project and 3D printing class is including teaching resources, skill development, and knowledge expanding.

The course of 3D printing technology contains theory and experience sections. For theory section, the theory of 3D scanning technology and different 3D printing technology are learned, including FDM, SLA, SLS, and 3-dimensional processing (3DP). For experience section, operating 3D scanning machine, treating the scanning data and reconstruction of 3D model, creating digital 3D models by NX software, treating the STL model and optimization, operating FDM machine are required. To training innovation and scientific literacy of students, every content of the science project were integrated in the suitable section of 3D printing technology course, as shown in Figure 2.

3.2 Practical Training after Class

Hands-on experience is a crucial aspect of practical training programs. Students should have ample opportunities to work with 3D printers, experimenting with different materials, settings, and techniques. This experiential learning approach allows students to develop a deep understanding of the capabilities and limitations of 3D printing technology, as well as the ability to troubleshoot common issues. In addition to technical skills, practical training programs should also focus on developing students' soft skills, such as creativity, critical thinking, teamwork, and communication. These skills are essential for success in the rapidly evolving field of 3D printing and the broader context of Industry 4.0. Collaborative projects, design challenges, and presentations can be incorporated into the curriculum to foster the development of these skills [34]. Moreover, practical projects and case studies should be integrated into the curriculum, enabling students to apply their knowledge to real-world scenarios and develop problem-solving skills [32].

As shown in Figure 3, in this study, students were required to manufacture 3D printing materials according to the science project about “Research and development of key technologies for biomedical piezoelectric composite materials based on 3D printed intervertebral fusion devices” in lab. At first, students must search the knowledge of polymer about intervertebral fusion devices. During this process, students can learn about the relevant knowledge of 3D printed polymer materials suitable for intervertebral fusion devices. After selecting the appropriate materials, students use AI to write experimental plans, modify them based on the actual research project, and determine the final experimental plan through group discussions. During the process of modifying and discussing experimental plans, students' critical thinking skills are trained and a scientific way of thinking is formed. After the experimental plan is determined, students will communicate with different material manufacturers to purchase the target materials. During this process, students' communication and discernment skills can be exercised. Finally, students conducted experimental work on 3D printing research projects in the lab. During the experiment, students' hands-on ability can be exercised. When the experimental results are not ideal or there are problems during the experimental process, students will analyze the problem and think of ways to solve it. Therefore, students' ability to analyze and solve problems has been strengthened.

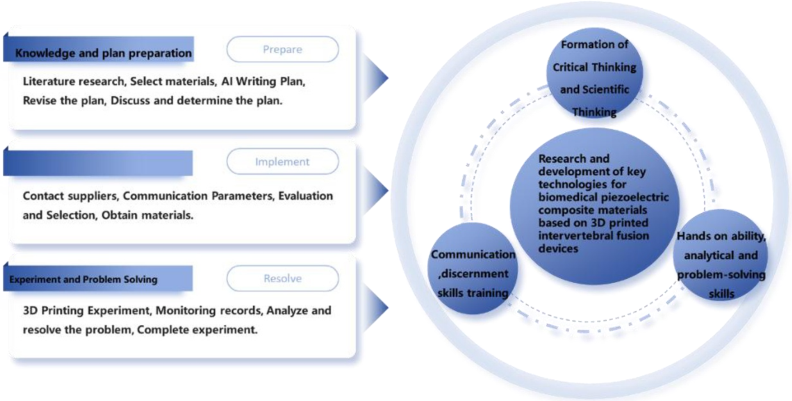

Fig. 3. Practical training content and abilities obtain

3.3 Assessment and Evaluation

Assessment and evaluation are critical components of practical training programs. As shown in Table 1, assessment and evaluation should be multi-dimensional. Students' progress should be regularly monitored, and their skills assessed using a combination of theoretical and practical evaluations. Formative assessments, such as project-based assignments and portfolios, can provide valuable feedback to students, helping them identify areas for improvement and track their progress over time. Summative assessments, such as final projects or industry-standard certifications, can demonstrate students' mastery of the required skills and knowledge [35]. To ensure the relevance and effectiveness of practical training programs, it is essential to collaborate with industry partners. These partnerships can provide valuable insights into current industry practices, emerging trends, and skill requirements. Industry experts can contribute to curriculum development, provide guest lectures, and offer internship opportunities for students. Such collaborations can also facilitate access to state-of-the-art equipment and resources, ensuring that students are trained on the latest technologies used in the field [33].

As shown in figure 4, for class A integrated 3D printing science project, the completion rate of "homework (15%)" is the highest, with an average score rate of

73.5%. The completion rate of "course audio and video (40%)" and "chapter quizzes (20%)" are low, with most students scoring less than 10%. The top 5 students in terms of comprehensive scores generally perform outstandingly in "course audio and video" and "chapter tests", with student A approaching full marks in both "course audio and video" and "chapter tests". For class B non-integrated 3D printing science project, the completion rate of "homework (15%)" is also relatively the highest, with an average score rate of 69.8%. The completion rate of "course audio and video (40%)" and "chapter quizzes (20%)" is extremely low, with over 90% of students scoring below 10%. Based the data in figure 4, it can be identified that the students in the class integrated in science project have higher level of learning motivation and is able to independently learn relevant content driven by scientific research projects.

Table 1. Assessment and evaluation contents of practical training programs.

<table>
<tr><th colspan="2">for Teachers</th></tr>
<tr><th>Aspect</th><th>Evaluation Content</th></tr>
<tr><td>Teaching & Research Enhancement</td><td>Integrating cutting-edge technologies and industry cases into teaching to enhance the relevance and practicality of course content; shifting instructional design towards project-based and inquiry-driven models; strengthening the ability to transform research outcomes into teaching resources; fostering interdisciplinary knowledge integration.</td></tr>
<tr><td>Career Development</td><td>Accumulating practical experience through participation in industry collaboration projects, supporting professional advancement and the production of teaching achievements; continuously refining teaching practices based on positive feedback from students and peers.</td></tr>
<tr><th colspan="2">for Students</th></tr>
<tr><th>Aspect</th><th>Evaluation Content</th></tr>
<tr><td>Knowledge & Skill Development</td><td>Exposure to the latest technological tools and industry standards; developing problem-solving abilities, innovative thinking, and teamwork skills through project-based learning in authentic contexts.</td></tr>
<tr><td>Practical Experience & Employability</td><td>Participation in internships, enterprise training projects, and research initiatives significantly boosts professional competitiveness, evidenced by higher rates of employment in related fields, increased starting salaries, and quicker adaptation to professional roles.</td></tr>
<tr><td>Long-term Development Potential</td><td>Cultivating potential for continuous learning and cross-disciplinary development, laying a solid foundation for future career growth.</td></tr>
<tr><th colspan="2">for Enterprises</th></tr>
<tr><th>Aspect</th><th>Evaluation Content</th></tr>
<tr><td>Talent Pipeline & Recruitment</td><td>Identifying and nurturing high-caliber talent that aligns with future needs through deep engagement in education, reducing recruitment costs and shortening onboarding periods.</td></tr>
<tr><td>Technology R&D & Problem-solving</td><td>Leveraging academic intellectual resources and research facilities to collaboratively address technical challenges, complete R&D projects, co-apply for intellectual property, and accelerate innovation translation.</td></tr>
</table>

Corporate Image & Social Benefits	Enhancing corporate public image and industry influence, strengthening its role within the industry-academia-research collaborative innovation ecosystem.

Class A demonstrates a strong concentration of students in the Good (54%) and Moderate (40%) performance categories, with no students scoring below 70 points.

The comprehensive performance of the two classes was compared, and the results were shown in figure 5. The analyzed results are as following: For overall performance level, Class A demonstrates significantly superior performance compared to class B, with a mean score 7.3 points higher and a good rate exceeding Class B by 20 percentage points. For Grade distribution characteristics, class A exhibits a more concentrated grade distribution with lower variability among students, while Mold class B shows greater dispersion in student performance. For performance structure differences, class A is predominantly composed of students in the Good and Moderate performance categories, whereas class B contains a substantial proportion (15.09%) of students in the Pass category with a notably lower minimum score. For pedagogical Implications, class A targeted interventions for academically challenged students are recommended. In general, the comprehensive performance of class A integrated science project is better than class B.

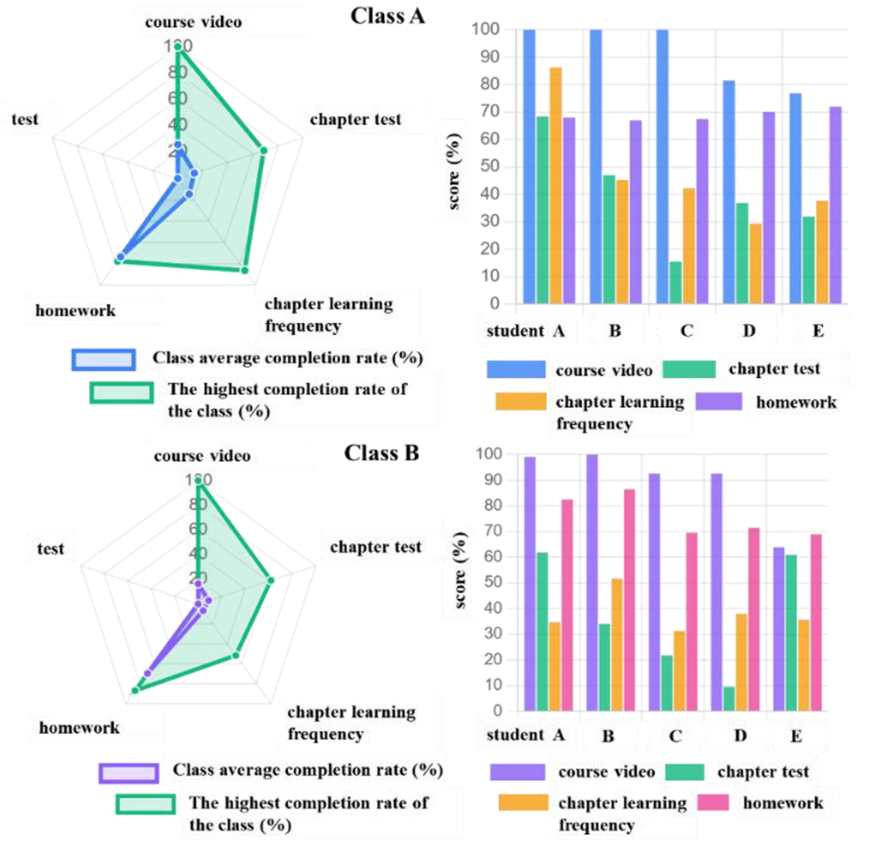

Fig. 4. Comparison of learning behavior between two classes of students

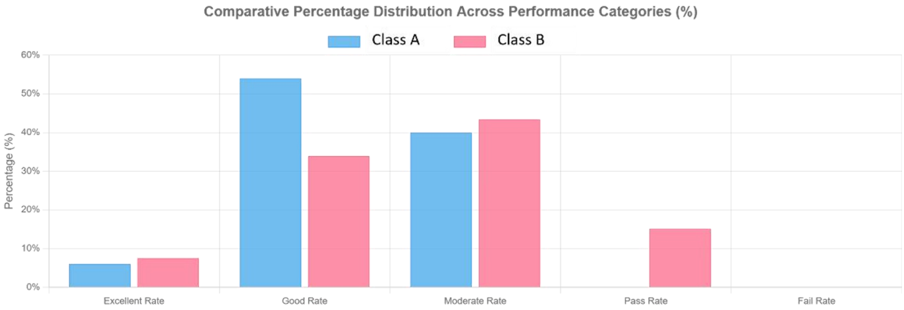

Fig. 5. Comparative analysis of class performance

4 Conclusion

In conclusion, practical training programs are vital for integrating 3D printing technology into educational curricula and developing high-skilled talent. These programs should be designed to provide students with hands-on experience, industry-relevant knowledge, and the soft skills necessary for success in the field. Collaboration with industry partners, regular assessment and evaluation, and a commitment to continuous improvement are essential for ensuring the effectiveness and long-term success of these programs. By implementing well-designed practical training programs, educational institutions can bridge the gap between academia and industry, preparing students to meet the demands of the new production paradigm and contribute to the advancement of 3D printing technology. To ensure the long-term success and sustainability of practical training programs, it is essential to establish a framework for continuous improvement. This involves regularly reviewing and updating the curriculum to reflect advances in 3D printing technology, changes in industry requirements, and feedback from students and industry partners. Additionally, investing in the professional development of faculty and staff is crucial to maintain their expertise and ensure they can effectively guide students through the rapidly evolving landscape of 3D printing. In this paper, our data collection is limited to the learning situation of two classes in the mold major at a single school. In future research, we will expand the scope of majors and classes in the experimental group to obtain a widely applicable teaching model that integrates science and education.

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