

Exploring a Novel Approach to Establishing a Geoscience 3D Printing Lab in the Era of Digital Earth

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Abstract: The rapid development of Digital China necessitates the cultivation of millions of individuals equipped with digital knowledge structures and practical abilities. The establishment of digital laboratories represents a significant innovation in teaching and management. This research endeavors to explore the construction of a geoscience 3D printing laboratory within the framework of the digital Earth, employing a well-designed integration of hardware and soft environments. The laboratory offers a comprehensive platform for teaching, research, innovation, and learning for both educators and students, leveraging state-of-the-art computer technologies. By incorporating 3D modeling and 3D printing technologies into laboratory teaching, a seamless connection between theoretical instruction and practical application is achieved, fostering reciprocal reinforcement between teaching and learning. With the support of the geoscience 3D printing laboratory, students have accomplished notable achievements, such as patent publications and research papers, as well as outstanding performance in various competitions at all levels. These accomplishments demonstrate that this model has effectively stimulated students' enthusiasm for learning, enhanced their problem-solving skills, and unveiled a promising pathway for the development of geoscience 3D printing laboratories in nurturing digital talents.

Keywords: Digital Earth, Innovative talents, 3D printing, Laboratory construction.

1. Introduction

In the global wave of digitalization, emerging technologies such as the metaverse and artificial intelligence are rapidly advancing, bringing profound impacts to various industries. Consequently, there is an increasing demand for scientific and technological innovation talents, especially in emerging fields. Among them, 3D printing technology, as an interdisciplinary emerging technology, has become a highly sought-after innovation frontier in various industries, and its practical applications in the education sector have already demonstrated its power. At the same time, the concept of the digital Earth in the field of Earth sciences provides us with a new research objective and methodology. Therefore, combining 3D printing technology with the concept of the digital Earth, it becomes an important task to construct a new type of university laboratory to cultivate innovative talents that meet the needs of the times.

University laboratories are important places for teaching and scientific research, bearing the responsibilities of experimental teaching, scientific research, and practical production. Laboratories not only provide experimental equipment and space but also cultivate students' rigorous thinking, inventiveness, and scientific work attitude.

In the context of digitalization, the core issue regarding the construction of a geoscience 3D printing laboratory is the optimization of the hardware and soft environments. This includes aspects such as laboratory layout design, open course settings, 3D printing associations, competitions at various levels and in various disciplines. By establishing a new model for geoscience 3D printing laboratories in the context of the digital Earth, we aim to cultivate high-quality talents with innovative thinking, innovative capabilities, and a multidisciplinary perspective. This will provide new insights and directions for our higher education industry, driving it towards a more innovative, open, and high-quality direction.

2. 3D printing and Digital Earth

3D printing technology encompasses the integration of virtual simulation, three-dimensional mathematical modeling, computer-aided manufacturing, and other information technologies with material sciences. It serves as a remarkable outcome of interdisciplinary integration and has significantly impacted various fields, including military aerospace, healthcare, education, fashion, and jewelry design. However, the application of 3D printing technology in Earth sciences, particularly within the domain of geoscience research in the context of the digital Earth, requires further exploration.

The concept of the digital Earth entails a comprehensive digital representation and simulation of spatial data related to the Earth's surface, made possible through the utilization of information technology. Digital Earth technology empowers us to observe, study, and predict intricate details about our planet.

The profound integration of 3D printing technology with the realm of geoscience has unlocked new avenues for laboratory research and teaching. By exploring innovative models for geoscience 3D printing laboratories within the digital Earth framework, this paper aims to optimize the design of laboratory layouts, establish open laboratory courses, facilitate the formation of 3D printing associations, and guide participation in various levels of competitions. These approaches are designed to cultivate a new generation of adaptable talents who possess innovative thinking, multidisciplinary perspectives, and the ability to thrive in a rapidly evolving world.

3. Content of Establishing Geoscience 3D Printing Lab

Laboratory construction is a complex and important task. In this paper, we will discuss it in terms of both the hardware

and soft function aspects. In terms of hardware construction, the laboratory is physically divided into a printing area and a modeling area [7]. In terms of soft function construction, we create a vibrant and innovative learning atmosphere by implementing open courses, supporting entrepreneurship and innovation competitions, organizing science and technology

club activities, promoting collaboration between universities and industry and military. These initiatives aim to cultivate students' innovative spirit and practical abilities, and ultimately contribute to society by producing more highly skilled and innovative talents.

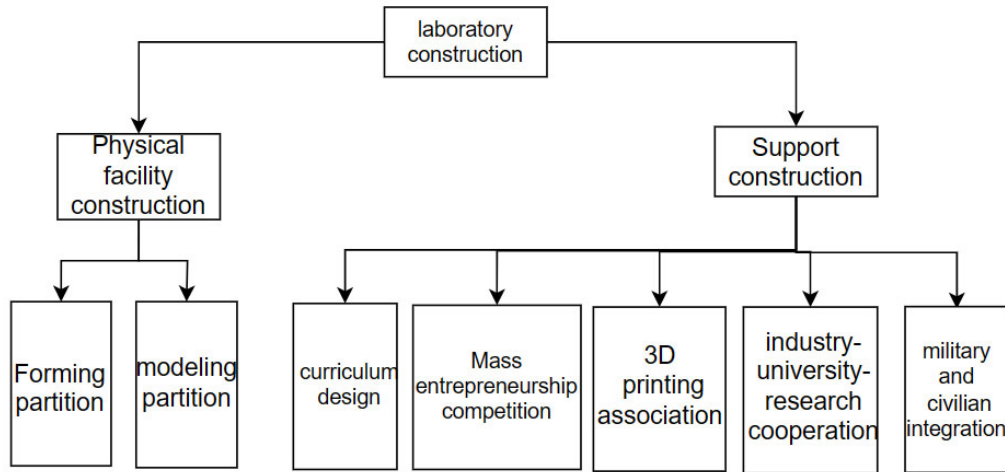


Figure 1. Frame diagram of the laboratory construction

3.1. Hardware Equipment and Layouts

The laboratory space is structured into a printing area and a modeling area. The printing area serves as the workspace for 3D printers, while the modeling area is where students build their models. As shown in Figure 2, the layout design

separates the printers, aiming to provide a more convenient environment for the daily operation and teaching research of the laboratory, while ensuring the safety of the experimenters through rational spatial planning and equipment deployment [8].

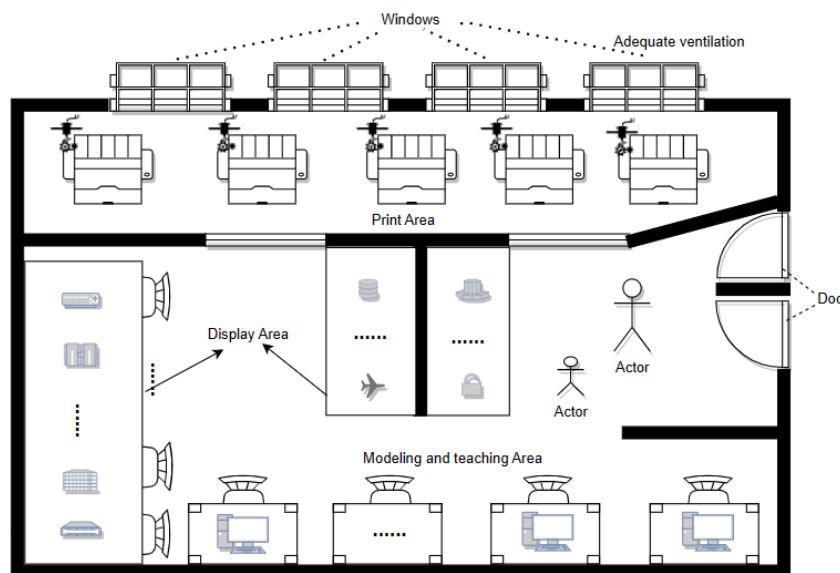


Figure 2. Space structure of 3D printing laboratory

3.1.1. Printing Area

In the printing area of the laboratory, an Intel i7 series personal computer with a dedicated graphics card is installed. This computer serves as the control center for managing and operating multiple advanced 3D printing devices. The

computer is connected to the Projet 660 Pro full-color 3D printer from 3D Systems, which utilizes a fixed IP address for connection to enable efficient data transfer and operational control. Additionally, the Hori Z500 3D printer and Uniz Plus LCD 3D printer are also equipped.



Figure 3. 3D printing equipment

The research paper titled "Assessment and Management of Human Health Impacts from 3D Printing Emissions" provides a comprehensive evaluation of the toxicity associated with particulate matter generated during the 3D printing process [9]. By conducting experiments and analysis, the study highlights the potential risks posed by these particles to human health, specifically their capacity to induce moderate toxicity in lung cells. Consequently, in the planning of the laboratory's physical environment, we have implemented a

series of measures to effectively mitigate the potential hazards associated with 3D printing emissions on human health. Firstly, we have selected 3D printers equipped with efficient filtration systems, ensuring that the exhaust is directed outdoors to minimize the dispersion of particles within the laboratory. Secondly, we have strictly adhered to the principle of separating humans from the machines by establishing dedicated printing areas furnished with high-performance ventilation systems, as depicted in Figure 4.

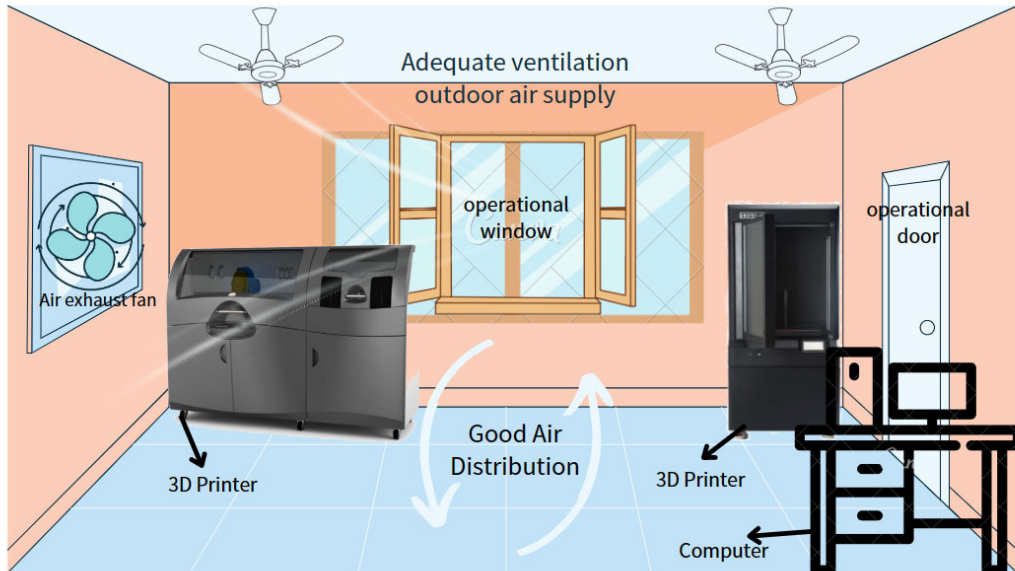


Figure 4. Ventilation system diagram of forming area

Furthermore, we maintain rigorous compliance with the laboratory's safety regulations when operating the printing area. To ensure optimal conditions, we prioritize excellent ventilation within the laboratory and limit the time spent by personnel in the printing area, adhering to the principle of swift entry and exit. When utilizing the 3D printer, it is mandatory for all participating faculty and students to employ industrial-grade masks of N95 or higher, as well as wear goggles, anti-static clothing, and nitrile gloves. These safety measures are strictly enforced to safeguard the physical well-being of all individuals involved in the experiment [10].

3.1.2. Modeling Area

The modeling area within the laboratory is thoughtfully designed to cater to the diverse needs and working styles of different students. It is subdivided into a public discussion zone and an individual creation zone, each serving distinct purposes. In the public discussion zone, there are 7-10 fully equipped PC workstations provided to foster collective

wisdom and facilitate the exchange of knowledge among students [10]. On the other hand, the individual creation zone offers students a dedicated space for independent work and personal expression. It is furnished with suitable desks and chairs, creating a comfortable working environment conducive to individual creativity [10].

Furthermore, the modeling area is organized into five distinct working groups based on the method of model creation. These groups encompass the Popular Software Modeling Team, Mobile Photogrammetry Modeling Team, Reusable Model Library Maintenance Team, Existing Data Conversion Team, and Complex Model Modeling Team. Each group tackles crucial stages of the modeling process, ranging from geological data collection and processing to modeling and design, material selection and optimization, printing and post-processing, as well as quality control and evaluation.

a. Popular Software Modeling Team: Equipped with high-performance PC workstations, this team utilizes popular modeling software such as Maya, Blender, SolidWorks,

Rhino, SketchUp, among others, to carry out geological data modeling and design tasks. Students can leverage these tools to process data and create precise geological models, as depicted in Figure 5.

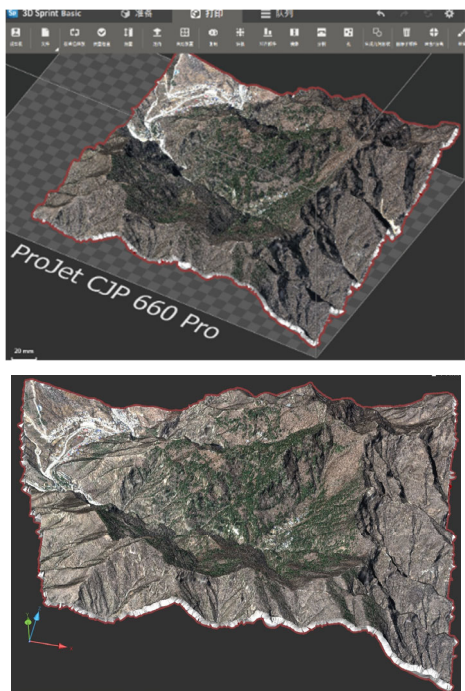


Figure 5. Geoscience terrain model

b. Mobile Photogrammetry Modeling Team: This team focuses on capturing images of field rock, mineral, and fossil specimens using mobile phones and utilizing software such as Agisoft PhotoScan and ColMap for modeling. Students capture images of on-site samples by taking photos and then use the software to generate accurate three-dimensional models, as shown in Figure 6.

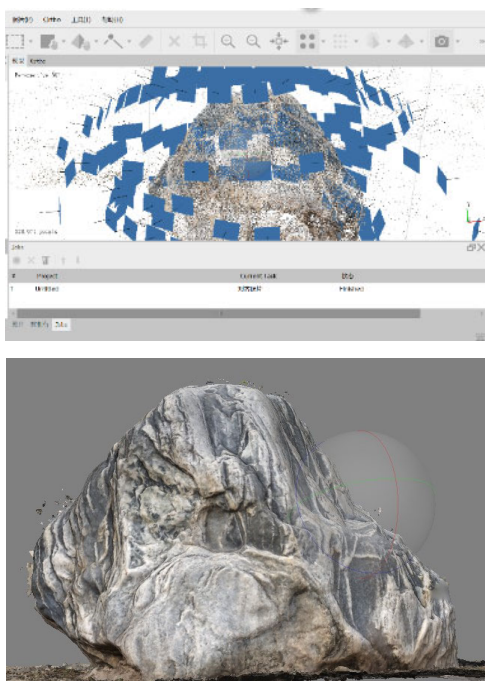


Figure 6. Modeling diagram of sample shooting

c. Reusable Model Library Maintenance Team: This work

area is responsible for the regular collection and organization of printed models within the laboratory. The models are carefully classified and stored based on geological categories, graduation theses, competitions, innovation projects, and post-class assignments. This systematic approach enables teachers and students to easily locate and utilize existing model resources, eliminating duplication of efforts and saving valuable time and resources in teaching and research activities.

d. Existing Data Conversion Team: To ensure compatibility between geological data and 3D printers, the Existing Data Conversion Team focuses on three-dimensional modeling of geological data[13]. The PC in the work area is equipped with software such as Surpac, GoCAD, and Petrel to facilitate the conversion into file formats readable by 3D printers. This conversion process ensures seamless integration of geological data with 3D printing technology, providing students with greater creative possibilities[14].

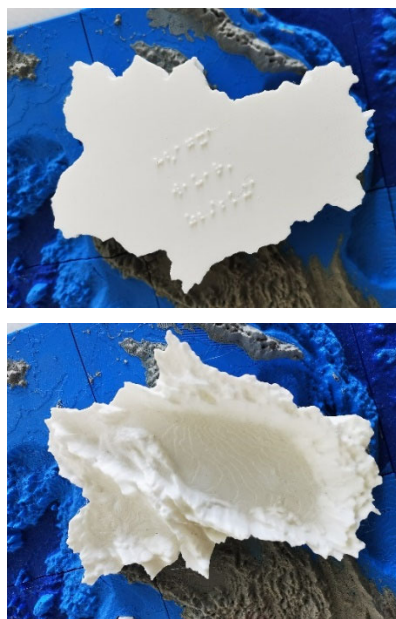


Figure 7. DEM conversion of high-resolution remote sensing images

e. Complex Modeling Team: To address the requirements of complex model modeling, a dedicated team called the Complex Modeling Team has been established, consisting of relevant faculty and students. This team primarily handles modeling tasks that involve special complexity and challenges, aiming to fulfill the advanced modeling needs of teachers and students.

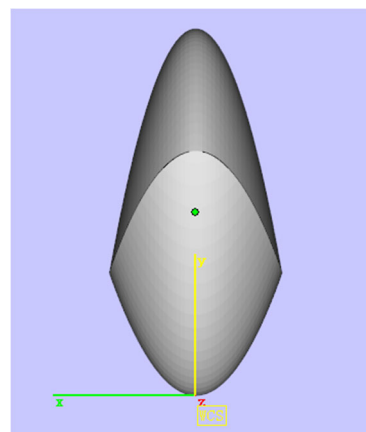


Figure 8. Diagram of a curved cylinder

3.2. Establishing Lab Soft Functions

As the main platform for developing practical skills and fostering innovative thinking, the Geoscience 3D Printing Laboratory implements the work of cultivating virtue and talents in the new era. It responds to the trend of educational informatization, promotes the deep integration of modern information technology and experimental teaching, expands the breadth and depth of experimental teaching content, and improves the quality and level of experimental teaching[13-15].

By participating in innovation projects, various competitions, the 3D Printing Association, industry-academia-research collaboration projects, and military-civilian integration projects, students are provided with opportunities to enter the laboratory and research teams early on. High-level scientific research supports high-quality

education and teaching, cultivates innovative talents, and fosters strategic scientific and technological talents, technology leaders, and innovative teams with international standards.

As a representative of modern information technology, 3D printing technology is an important innovation tool. The Geological 3D Printing Laboratory provides research directions and technical support for students to participate in innovation projects, various competitions, the 3D Printing Association, industry-academia-research collaboration projects, and military-civilian integration projects. Through the continuous update and construction of the laboratory's software environment to accommodate various projects, students are gradually trained to become innovative, skilled, and application-oriented talents who can respond to the demands of the times[16].

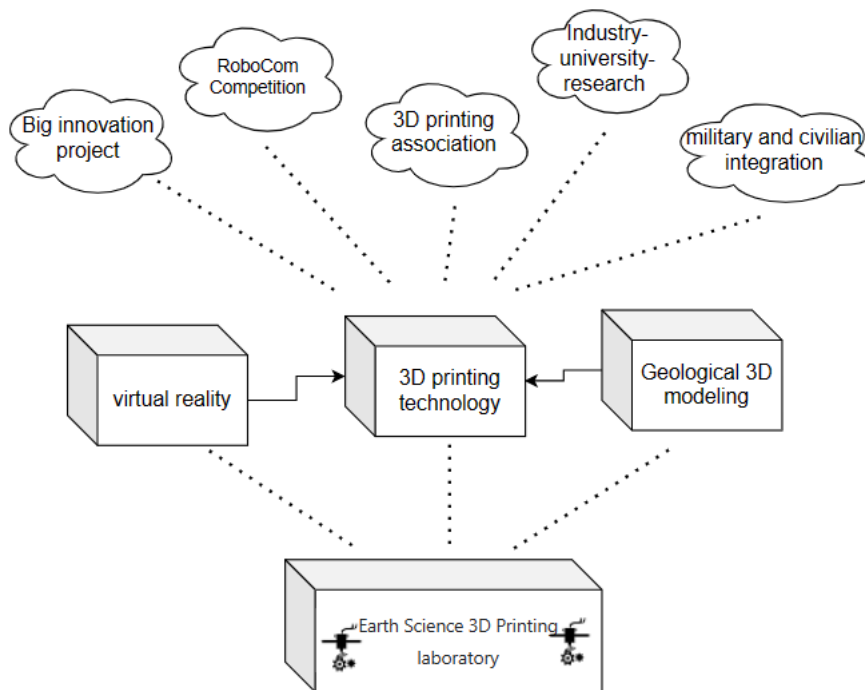


Figure 9. Construction structure diagram of soft environment

3.2.1. Designing Open Course

Open laboratory courses are exploratory experimental courses offered to students of all majors and grades based on the requirements of the teaching syllabus. The design of these courses aims to create an academic environment for students to explore and cultivate their practical abilities, stimulate their innovative thinking, and foster their independent learning skills. Through open laboratory courses, students have the opportunity to autonomously select experimental topics, develop experimental plans, and engage in practical operations and data analysis.

Furthermore, the course design emphasizes interdisciplinary cross-collaboration and cooperative learning. Students can transcend disciplinary boundaries by choosing experimental courses relevant to their own major or ones they are interested in, and participate in experimental projects with

classmates from different academic backgrounds. This design facilitates collaboration and communication among students, while fostering teamwork and interdisciplinary thinking abilities.

3.2.2. Supporting Entrepreneurship and Innovation Competition

Based on the laboratory's innovation and entrepreneurship projects, as well as various competitions, students have achieved fruitful results in the field of scientific and technological innovation. These results are presented in Table 1. Innovation and entrepreneurship projects, along with competitions, are important components of students' innovative practices. They not only provide a platform to showcase talent and innovative achievements but also inspire students' motivation for independent learning. Additionally, they foster the ability to collaborate in interdisciplinary teams.

Table 1. Situation of the Entrepreneurship and Innovation competition

Category	2019	2020	2021	2022	Results
Number of innovation and entrepreneurship projects	6	8	11	9	Utility model: 2 items Invention patents: 2 items CPCI paper: 1 article MDP paper: 1 article
Number of participants in each category	6	10	10	12	National first prize: 3 items National second prize: 1 item National third prize: 2 items

3.2.3. Establishing 3D Printing Technology Association

Relying on the laboratory, the 3D Printing Technology Association is established. The association regularly organizes training seminars and sharing sessions on popular software and technical advancements. Members from different grades and majors form teams to participate in daily learning, innovation projects, and various competitions. By applying a multidisciplinary and cutting-edge scientific approach, they address scientific problems within their respective fields of expertise.

into the latest industry trends and development. Through the collaboration between the university and the company, we are able to fully leverage industry resources and establish a bridge for industry-academia collaboration. This provides students with opportunities for field visits and on-site learning, enabling them to gain in-depth understanding of the manufacturing processes and working principles of various components. It also offers internship and employment opportunities, laying a solid foundation for their professional development. [2].



Figure 10. 3D printing popular science publicity diagram

3.2.4. Building Industrial Collaboration

By fully utilizing the advantages of enterprises and industry resources, we have established close cooperation with Beijing Space Intelligent Construction Technology Co., Ltd. Through the implementation of industry-education integration, we have personally experienced the actual working environment and the production practices of the company, gaining insights

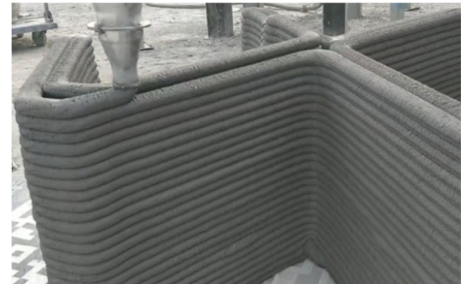


Figure 11. Production practice diagram of production, education and research enterprises

3.2.5. Building Military Collaboration

Military-civilian integration and collaborative construction between the military and civilian sectors: In terms of military-civilian integration, we actively promote collaborative construction and cooperation between the military and civilian sectors. This includes the joint construction of our 3D printing laboratory with a certain engineering university laboratory, aiming to achieve resource sharing, mutual exchange of experiences, and facilitate the sharing and communication of research achievements.

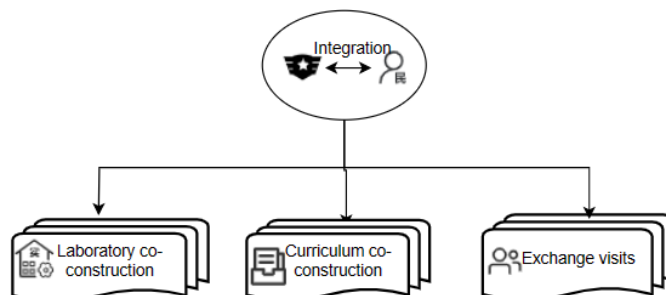


Figure 12. Architecture diagram of civil-military fusion

The collaboration of military-civilian integration is not only reflected in the joint construction of laboratories but also extends to the joint development of experimental and internship courses. Together, we formulate and implement experimental and internship courses to enhance students' practical abilities and overall qualities through practical activities. Students have the opportunity to visit and exchange ideas with each other among different laboratories, broadening their academic perspectives and improving their research and innovation capabilities[17-18].

4. Results

4.1. Printed product:

After the coordinated construction of both the hardware and soft environment in the laboratory, significant results have been achieved. The following are examples of student classroom works, competition awards, and innovation projects

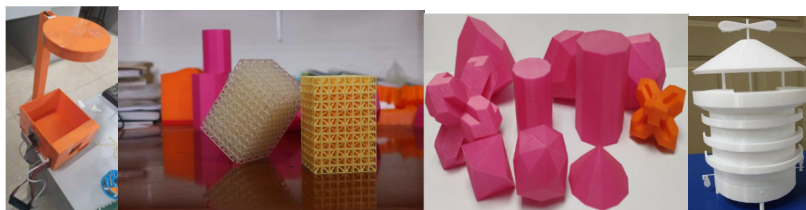


Figure 13. Students' classroom works display

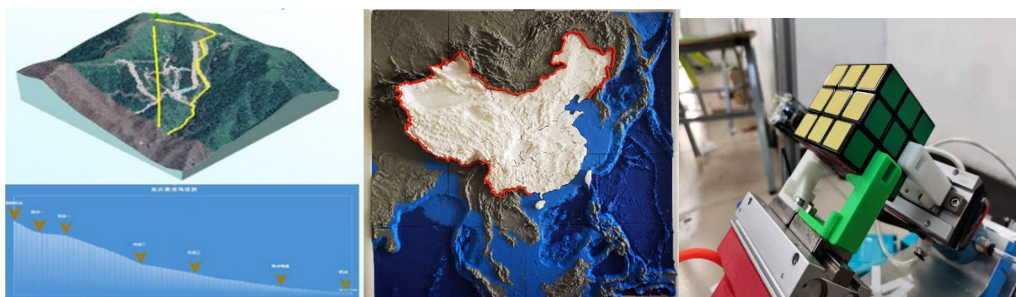


Figure 14. Entries and Awards



Figure 15. Prize-winning results display diagram

5. Conclusion

The laboratory is a distinctive place that embodies the spirit, culture, and academic level of a university. It is also one of the main indicators of a school's academic and research capabilities. It is undeniable that compared to world-class universities abroad, there is still a significant gap in the conditions of our experiments. We must catch up. Therefore, we need to broaden our thinking in terms of laboratory infrastructure, be bold in exploration and experimentation, and, at the same time, ensure laboratory safety through the responsible system of experimental teachers. We should adopt a flexible and autonomous laboratory management approach, providing a platform and technical support for students and teachers to participate in various competitions, innovation projects, and other activities. This will safeguard the continuous growth of students and explore a geological 3D printing laboratory construction model that nurtures talents with adaptability, exploratory mindset, creativity, and pioneering spirit to meet the developmental needs of the times.

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