Exploration of the Flipped Classroom Educational Model for Cognitive Education of Specialized Computer Majors

Han Luo[1,2,*], Lei He[1,2], Bin Liu[1,2], Yanyan Huang[1,2], Xiaojia Bi[1,2]

[1]*School of Software Engineering, Chengdu University of Information Technology, Chengdu, Sichuan, China*

[2]*Sichuan Province Engineering Technology Research Centre of Support Software of Informatization Application, Chengdu, Sichuan, China*

[*]*Corresponding Author*

Abstract: Fostered by advancements of information technologies, especially those in big data, cloud computing and artificial intelligence, undergraduate computer science education is becoming more specified and refined, and numerous sub-majors are developed to meet specific societal demands. Being an interdisciplinary, comprehensive, and fast-developing subject with limited public awareness, professional cognition and engineering literacy are at the core of an introductory course that aims to materialize the spirit of emerging engineering education. Based on a framework that conducts demand identification, plan design, and implementation pathway in a logical order, we develop a flipped classroom model for our introductory course of Spatial Information and Digital Technology. Guided by the idea of backward design, the course objective is framed with consideration of graduation objectives and the characteristics of freshmen. This flipped classroom model is task-oriented and synthesizes individual and collaborative learning to engage the students and cultivate their problem-solving skills. The model incorporates several managerial innovations to guarantee the efficacy, including interdisciplinary teaching teams, blended learning strategies, and process-oriented evaluation. These measures not only optimize the teaching procedure, but also offer the students broader resources and more opportunities for practice. In conclusion, our introductory course framework successfully puts forward a route of cultivating the professional identity and engineering literacy of freshmen, which constitutes an attempt strongly supportive of the emerging engineering education.

Keywords: Output-oriented; Professional Cognition; Engineering Literacy; Task-oriented; Flipped Classroom; Blended Learning; Spatial Information and Digital Technology;

1. Introduction

Due to the rapid development of technology and the emergence of fields such as artificial intelligence, big data, cloud computing, the internet of things, and virtual reality, there is an enormous demand for qualified professionals in a variety of fields, including finance, healthcare, and education [1]. The undergraduate education training system for computer-related majors is progressively adapting toward specialization and refinement in order to better meet market demands. Ensuing biotechnology and nanotechnology, spatial information technology has been recognized as one of the technologies having the greatest potential [2]. As a result, the major of spatial information and digital technology (SIDT) was established. This major is a specialized program within the computer science based on software engineering. It initiates an interdisciplinary integration of computer science, information science, surveying science, and earth science [3,4]. In order to take advantage of spatial information in a variety of professional fields, including agriculture, energy, and meteorology, it focuses on the digital transformation of spatial objectives through the application of software development.

The requirement for engineering identification education in undergraduate education has increased in the context of emerging engineering education. In the meanwhile, SIDT has extensive content and integrate multiple disciplines. According to a survey of SIDT major training programs in 21 Chinese universities (Figure 1), more than 80% of the training programs contain an introductory course, and some offer two courses to give freshmen an introduction to both fundamental professional knowledge and engineering practice. In order to effectively motive the students, advance their understanding to their major, and develop their engineering capabilities within the framework of engineering cognition, introductory courses for SIDT are now designed with innovative course design strategies in mind.

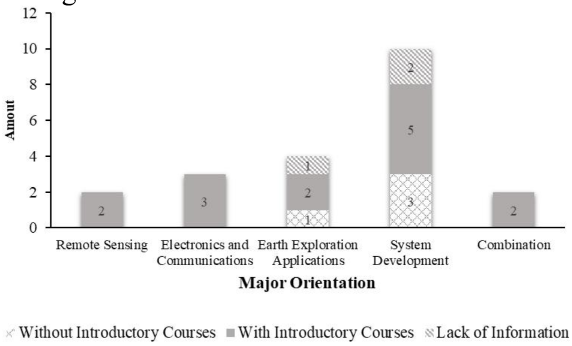

Figure 1. The Survey Results on the Training Programs of SIDT in 21 Chinese Universities

In the undergraduate educational system, introductory courses are essential for students to facilitate transition between educational stages and for igniting their curiosity about new topics and creative thinking [5,6]. According to the International Engineering Education Alliance, introductory courses must aid students in acquiring skills of a training program and evaluate their self-motivation [7], demonstrating that the goal of introductory course is to improve engineering cognition and expand professional knowledge. The related research focused on helping students develop their professional cognition and engineering literacy through a variety of perspectives, including innovation and entrepreneurship [8], innovative [9] and engineering thinking [6]. Some researchers have divided introductory courses into five cognitive modes: seminar, experimental, design, and practical [10,11].

This article explores innovative design models for introductory courses in specialized computer majors, starting with task-oriented approaches. This approach for flipped course instruction leverages both individual and collaborative learning. The framework involves numerous factors, including course objectives, content, and teaching administration, to acquire a better understanding of cognitive education's depth and breadth. The objective is to enhance students' professional skills and abilities by creating a new path that combines professional cognition and engineering literacy development for freshman in computer science specializations.

2. Framework for Professional Cognition and Engineering Literacy Cultivation in Task-Oriented Flipped Classrooms

The flipped course education framework focuses on professional cognition and early development of engineering literacy for freshmen by addressing course objectives, content, and classroom management. The course objectives, content, methodologies, and activities were designed to address significant challenges in the introductory course, following the paradigm of "demand identification - program design - implementation pathway" (Figure 2). This course design responds to engineering education needs, enhances professional cognition, and ignites students' enthusiasm in computer science, setting a strong basis for future professional development.

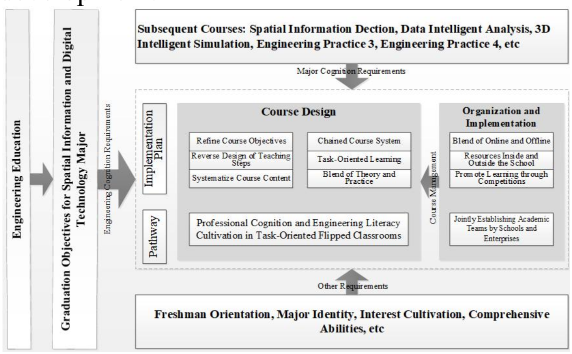

Figure 2. Pathway for Teaching Design in the Introductory Course of SIDT

2.1 Refinement of Course Objectives

The introductory course on SIDT is designed to efficiently enable the freshmen to acquire the key fundamental and practical abilities for future engineers, and develop engineering literacy as well. Therefore, in addition to establishing a foundation of professional knowledge, students must understand the close relationship among engineering, science, and SIDT from a broader perspective, develop the systematic cognitive framework for the engineering, and the foundation for engineering thinking and capabilities. The learning outcome-oriented strategy and reverse teaching design are used to define course objectives and facilitate mutual-support between course content and teaching sessions (Figure 3).

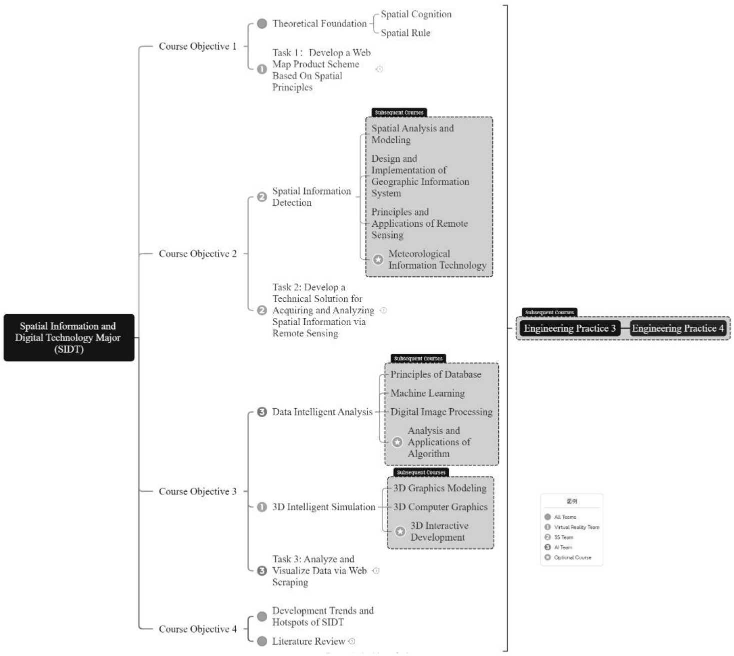

Figure 3. Knowledge System Integration Based on Course Objectives and Design of Course Scheduling

During the course, students must complete three projects and a literature report, which involve resorting to online literary resources, organizing team conversations, and dealing with problems in various professional fields. It entails recognizing the value of collaboration, identifying professional and technical skills, and allocating resources to address critical issues. Furthermore, students must enhance their ability to evaluate and validate solutions using both internal and external resources. These activities not only assist students gain traditional professional knowledge, but also support the development of their abilities, setting the foundation for their future goals, no matter those are industry jobs or graduate training.

2.2 Integration of Course Content

The introductory course provides the first opportunity for freshmen in engineering to enter the professional field. Its main objective is to help students understand SIDT's concept and scope as well as the core skills and knowledge required in this sector. As a typical multidisciplinary discipline, the majors of SIDT may have different program designs at different schools based on their positioning and specialty. At the same time, it's important to keep up with the latest technology and research in SIDT, such as machine learning, intelligent algorithms, spatial data mining, and spatial scenario technologies like augmented and virtual reality.

To scientifically integrate the course content, the course is based on three directions: spatial information detection, data intelligence analysis, and three-dimensional simulation. It restructures knowledge framework of the course and divides the objectives into four parts (Figure 3). In order to lay the foundation for the follow-up courses, such as remote sensing principles and applications, spatial analysis and modeling, three-dimensional computer graphics, and engineering practice, corresponding classes are organized based on their quota in the graduation objectives and the course difficulty.

2.3 Design of Task-oriented Flipped Classroom

In the context of emerging engineering education, modern engineering education places a strong emphasis on student-centered approaches, encourages autonomy, teamwork, and explorative learning in order to ignite students' interest and develop their practical abilities. Under this paradigm, teachers and students both play significant roles in the class through the completion of three course assignments and one literary report.

The first task is to develop a web map product scheme based on spatial-rules. Students are expected to focus on the design of web map products, while also investigating and understanding the underlying rationale and technical implementation. Based on standards such as the Basic Requirements for the Safe Processing of Navigation Electronic Map (GB20263-2006), they must analyze online map products, construct typical application scenarios, and propose web map product design schemes with consideration on functional planning, interface design, interaction logic, data processing, and visualization. Task 2 involves developing a technical solution for acquiring and analyzing spatial information via remote sensing. Students are encouraged to concentrate on environmental protection and sustainable development, identify common engineering issues related to spatial information and digital technology, choose appropriate remote sensing images, and develop a technical solution for spatial information acquisition and data analysis. The third task is to analyze and visualize data via web scraping. Students will learn how to use internet scraping technology to collect data, and visually present the results for decision-making or problem-solving. In the literature review task on current SIDT advances, students should develop a sense of the trend and hot research topics, based on their prior learning achievements and literature search. They should also create a study plan for their future professional learning.

The objective of this approach is to improve students' understanding of real-world engineering by putting theoretical knowledge into practice. It employs flipped classrooms and task-oriented learning to assist students in designing solutions, finalizing those ideas, and demonstrating how well their implementations perform in real-life scenarios.

2.4 Course Resources and Implementation

To address the difficulty of administering and evaluating flipped classrooms, as well as to improve teaching quality, the course team created a "blended teaching design" that incorporates both online and offline learning. By incorporating the most recent academic findings and literature, as well as utilizing multiple online teaching platforms, a learning platform for students has been developed, which opens a window into industrial trends, technological forefronts, and practical applications This method also accommodates instant feedback and in-depth analysis of learning results, which aids the creation of customized learning plans. In order to achieve a deep integration of theory and practice, a variety of teaching activities, including post-class reading and exercises, have been put into action to increase students' intrinsic motivation for learning and promote involvement in real-world activities, e.g., college student innovation and entrepreneurship competitions.

The course team designed a three-stage teaching method composed of "pre-class preparation, in-class implementation, and post-class consolidation", in order to systematically arrange the teaching process. It is built upon five core elements: enhancing classroom interaction participation, constructing a diversified assignment management system, strengthening experimental and hands-on operation abilities, analyzing course data and evaluating effectiveness, and continuously optimizing and constructing course resources.

The course team creates a collaborative network that consists of professionals from both academia and industry (Figure 4). Academics and experts from outside companies, academic institutions, and design institutions were invited to join the teaching group. The core team is made up of instructors with backgrounds in three areas: three-dimensional simulation, data intelligent analysis, and spatial information detection. Through close cooperation between internal and external teachers and specialists, the theories, professional knowledge, skills, research, and engineering practice experience in the disciplines of SIDT are fused for effective instruction. Based on the three tasks, every 3-4 students are grouped into a unit in close contact with the teachers to ensure that students give timely feedback and get supervising advices in time. Students must provide thorough comments on projects, give filmed presentations, and upload the videos to the teaching platform. Finally, the best teams are nominated on the basis of student votes and overall evaluation by teachers.

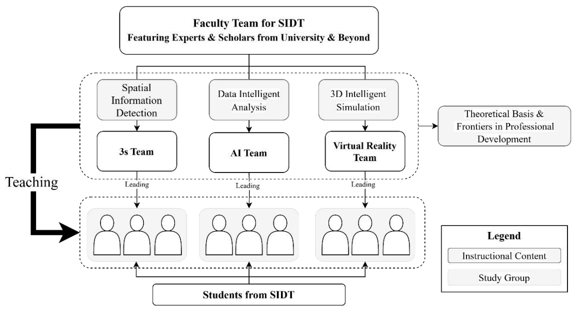

Figure 4. The Framework of the Mixed Faculty Team for SIDT

Faced with future engineering and societal demands, in the implementation, progress of every student is tracked to prevent plagiarism. Open-mindedness is encouraged, and stray discussions should be corrected timely. To promote excellence, the good-performing teams are recommended for College Student Innovation and Entrepreneurship Competitions, Internet + , and so on.

3. The Effects of Educational Model on Learning Outcomes

Students' involvement and sense of success increased significantly when the educational approach was implemented in the introductory course. Subjective questionnaire surveys suggest that our curse considerably improved the students' comprehension of engineering and majors (Figure 5). Just 8% of students in 2020 knew the fundamentals. After the course, this percentage rose to 52%. Additionally, as the course design is continuously updated and enhanced, the percentage of students that are significantly benefited gradually increases. The course effectively motivated the students to participate in college innovation and entrepreneurial competitions.

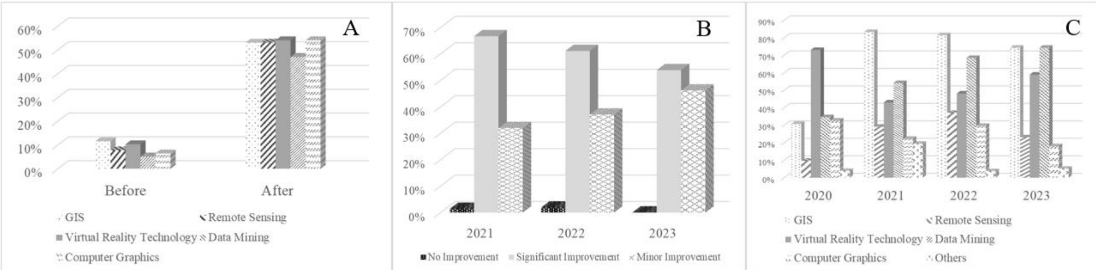

Figure 5. Analysis of the Survey Results on Course Implementation

A: The result of students in 2020 with a basic understanding of the major before and after the introductory course; B: The improvement of major and engineering cognition after the introductory course from 2021 to 2023; C: The survey results of students' interests in major after the introductory course from 2020 to 2023.

4. Conclusion

Drawing insights from relevant domestic and international research on cognitive models, we initiated and examined a "task-oriented professional cognition and engineering literacy cultivation" flipped classroom educational model in our introductory course of SIDT. Additionally, a task-driven flipped classroom teaching method is proposed. We firmly believe that the task-based flipped classroom teaching methods incorporated with engineering cases and practical content, not only prepares students for practical engineering challenges, but also instills a clear sense of identity, career awareness, and work conscientiousness at the very beginning of their engineering studies. This conclusion is based on a review and summary of the explorations and practices conducted over the years.

Although our exploration focuses on the introductory course of SIDT, the underlying teaching concepts and methodologies exhibit broad applicability. Backed up with appropriate adaptation, the task template in this work could apply to introductory courses in other sub-majors of computer science, thereby laying a solid foundation for cultivating more competitive and versatile engineers for the technology industry.

Acknowledgement

This study was supported by Undergraduate Education Teaching Research and Reform Project of Chengdu University of Information Technology (No. JYJG2021103, No. JYJG2024133), Undergraduate Education Teaching Research and Reform Project of the Software Engineering College, Chengdu University of Information Technology (No. SETRF202305).

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