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# Teaching reform and practice in GIS principles course: An innovation and entrepreneurship-oriented approach

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**Abstract**

Innovative teaching aims to develop students' innovative thinking and abilities through a wide range of innovative teaching activities and approaches. In this study, the implementation of the teaching process was summarized from three aspects: innovative teaching methods, innovative teaching content, and innovative teaching evaluations and feedback mechanisms, and the teaching achievements were also reflected upon based on the course of Principles of Geographic Information System (GIS). Among them, teaching methods have been innovated through four aspects: the transforming teaching methods, the combination of online and offline teaching models, case-based teaching, and project-based teaching; teaching content has been innovated through strengthen the practical training component and strengthen ideological and political teachings in the course; innovations in teaching assessment and feedback mechanisms have been made by building diverse assessment systems and providing timely feedback, as well as adapting aspects of teaching strategies. As a result, the theoretical level and practical skills of the students have been significantly enhanced, their practical abilities and innovative spirit have been effectively cultivated, and their overall quality has been comprehensively improved, laying a solid foundation for their future professional development.

**Keywords:** Innovative teaching, teaching methods, teaching content, Principles of GIS

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## 1. Introduction

In May 2010, the Ministry of Education of China issued the Opinions on vigorously promoting innovation and entrepreneurship education and college students' self-employment in higher education institutions, emphasizing that implementing innovation and entrepreneurship education in higher education institutions is a critical approach to deepening higher education teaching reform and fostering students' innovative spirit and practical abilities (Luo 2019; Zhang 2024a). Innovation and entrepreneurial education represent not only an essential requirement for educational reform, but also a response to the demands of the contemporary era (Li 2023). Furthermore, for higher education institutions, the establishment of innovation and entrepreneurship courses constitutes the core content and foundational framework for the effective implementation and exploration of such education (Zhu & Shu 2021).

Principles of GIS is a core professional course for students majoring in GIS at the School of Surveying and Urban Spatial Information at Henan University of Urban Construction. The quality of its instruction has a direct impact on a student's mastery of subsequent specialized courses and their future development within the relevant field. In recent years, with the rapid advances in technology and the growing societal demand for GIS expertise, traditional teaching methods have increasingly shown limitations in meeting the demands of modern education. Therefore, innovative teaching methods should be introduced into the teaching process to enhance educational effectiveness and foster practical skills and innovative thinking among students.

## 2. Course information

### *2.1 Basic information*

The course is structured into two components: a theoretical part and a practical part, based on the program's training objectives and graduation requirements. The theoretical part comprises 32 class hours, while the practical part includes 16 class hours, totalling 48 class hours (equivalent to 3.0 credits). This course focuses on introducing the fundamental theory and methodology of GIS, encompassing spatial data collection, processing and management,

 

spatial data analysis and synthesis, and the establishment and application of GIS systems. The aim is to enable students to understand and master the basic theories and methods of GIS science, to become proficient in operating GIS software, and to have the ability to analyze and solve practical problems using GIS tools. Students should also have a solid foundation in theoretical knowledge and skills, innovative thinking and adaptability, as well as a decent work ethic and humane qualities.

The teaching team consists of eight members, four with senior professional titles and four with intermediate professional titles. In the past three years, the team's teachers have won two second-place prizes in the Young Teacher Lecture Competition of the Survey and Mapping Specialty of Henan Higher Education Institution, and one second-place prize in the School-level Classroom Teaching Innovation Competition. We have undertaken one research project on educational teaching reform in higher education institutions of the Henan Provincial Department of Education, and have presided over 3 school-level research projects on higher education teaching reform, one school-level special prize for teaching achievements, one first prize for teaching achievements, two school-level application-oriented undergraduate courses, and two school-level ideological and political demonstration course.

### *2.2 Teaching objectives*

The specific course objectives and associated competency requirements are outlined below.

- Objective 1: Students need to grasp the basic concepts, the components of GIS principles, and the application and development of GIS; have the ability to acquire, edit and transform spatial data; be able to perform spatial analysis and expressions based on GIS engineering problems.
- Objective 2: Students should be able to understand the theory and methods of GIS. For specific problems, they can seek multiple solutions from different aspects by consulting materials and literature to obtain valid conclusions. The aim is to equip students with the ability to analyze and solve problems.
- Objective 3: Students can use the principles of GIS to gain an initial understanding of the development of GIS, and build corresponding experimental platforms to obtain and analyze data.

## 3. Teaching procedures

### *3.1 Innovation in teaching methods*

#### *3.1.1 Transformation of teaching methods*

The outcome-based education (OBE) concept, which is centered on anticipated completely outcomes, serves as a structured framework for organizing, implementing, and assessing educational processes (Gu *et al*. 2014). It emphasizes the principle of learner-centeredness (Zhang *et al*. 2020), shifting from the traditional teacher-centered instruction model to a student-centered instruction paradigm. The transformation aims to adequately engage students' enthusiasm and initiative in their learning journey, while fostering their creative thinking.

Prior to class, the teaching team collaboratively discusses and defines the expected learning outcomes for students, designing relevant questions and assignments via the Superstar Learning to support student preparation exploration and engagement. During class, targeted teaching strategies are employed, such as group discussions, group presentations, and Flipped Class Model (Figure 1a), with learning effectiveness evaluated through smart teaching methodology (Figure 1b). Teaching strategies are dynamically adjusted based on real-time feedback. After classes, assignments and quizzes are assigned to assess students' learning achievements, and teachers provide online guidance and clarification via QQ groups. As a result, the overarching teaching objectives are effectively achieved through these integrated approaches.

 


Figure 1. Flipped Class Model (a) and learning effectiveness assessment via smart-teaching-assisted instruction (b)

*3.1.2 Teaching mode integrating online and offline learning*

With the rapid development of technology and information, modern educational information technology has also advanced rapidly. Superstar Learning is an intelligent mobile learning software that provides students with rich learning resources that allow them to access information anytime, anywhere. In addition, teachers can interact with students online at any time through Superstar Learning, answering students' questions, assessing their learning outcomes, and providing prompt feedback on their knowledge mastery. Offline teaching, on the other hand, emphasizes face-to-face communication and interaction between teachers and students, enhancing understanding and mastery of basic concepts and skills through classroom discussions and hands-on operations. The integration of online and offline teaching models can better stimulate the interest and enthusiasm of students in learning, quickly grasp their learning situation, and effectively improve teaching effectiveness.

*3.1.3 Case-based teaching*

Case-based teaching is a teaching method in which teachers purposefully organize students to improve their ability to analyze and solve problems through activities such as investigation, analysis, discussion, and communication of cases (Zhang & Jin 2004; Ma 2024). To enable students to better understand and grasp the practical application of the Principles of GIS, a case-based teaching approach was used. By introducing real and specific cases, students are encouraged to analyze and solve practical problems, thereby developing their problem-solving abilities and innovative spirit. For example, in the chapter on spatial data analysis, the case of finding the best path for emergency services is used. First, the students were asked to think, discuss and communicate how an ambulance could reach the location of an injured person in the shortest possible time, in relation to the path they were taking. Second, students were guided to analyze the relationship between the length of time and the length of the path, as well as the factors affecting the speed of travel on the way (such as whether it passes through schools, pedestrian streets, etc.). Then, on the basis of this, the actual operation is carried out and the best route for the ambulance during the emergency process is given. Finally, based on the student's completion, the questions that occurred were commented on and directed, and case summaries were completed.

*3.1.4 Project-based teaching*

The core concept of project-based teaching lies in engaging students' interest through real-world problems, stimulating their critical thinking, and enabling them to acquire and apply original knowledge within the framework of problem-solving (Xu 2017; Zhao *et al*. 2019). In laboratory experiments and internships, project-based methods of teaching are predominantly employed. Students are divided into groups, each of which is responsible for a specific practical project. For example, in the internship component of the Principles of GIS course, the process unfolds as follows. 1) Orientation sessions were held for the interns to inform the students about the security protocol. 2) Based on the assigned internship program, students were instructed to systematically collect relevant data. 3) Tasks were assigned and group-based internships were implemented. 4) Instructors conducted inspections and organized task-based competitions. 5) An in-class summary was provided, along with an evaluation of the completed task. Throughout the project implementation process, students comprehensively apply the knowledge they have acquired, engage in practical operations, and draft project reports. With this approach, students can develop a deep understanding of the practical applications of GIS, enhance their practical skills, and strengthen their teamwork.

 

### *3.2 Innovations in teaching content*

#### *3.2.1 Strengthen the practical training component*

The Principles of GIS is a course characterized by its strong practicality. As a result, the design of practical teaching components has been significantly enhanced throughout the teaching process, with practical teaching hours accounting for 1/3 of the total course hours. By organizing students to work on computer-based operations, they are able to gain proficiency in GIS software operations while deepening their understanding of theoretical concepts. In addition, the diversity of practical teaching activities is emphasized, encompassing laboratory experiments, simulation exercises, curriculum internships, and curriculum design, all aimed at enhancing the comprehensive practical capabilities of students. For example, in the chapter on spatial analysis in GIS, training is done in three distinct aspects. First, in-class operational demonstrations are provided to illustrate the methods and procedures of spatial analysis in GIS. Second, post-class simulation exercises are conducted via a virtual simulation platform. Third, group competitions are organized to facilitate hands-on practical operations.

#### *3.2.2 Strengthen ideological and political education in courses*

Course-based ideological and political education represents a concrete measure for implementing the principle of fostering virtue and nurturing talent (Wang & Shi 2020), as well as an essential approach to cultivating individuals in the new era (Zhang 2024b). In the teaching of Principles of GIS, reinforcing course-based ideological and political education constitutes a critical step. It not only aids in the development of the ideological and political qualities of the students, but also directs them to integrate their professional knowledge with their social duties, thereby contributing to the advancement of the nation and society. The elements of course-based ideological and political education within the course of Principles of GIS have been systematically organized, with the results presented in Table 1.

In daily teaching, the integration of detailed ideological and political education within the Principles of GIS course is demonstrated through the following example. 1) It is crucial to nurture the patriotic spirit of the students. Through a detailed exploration of the evolution of GIS in China, students can gain a deeper understanding of what has been achieved in the field of GIS, thus arousing patriotic fervor among students. At the same time, guide students to understand the latest international development trends in GIS technology, broaden their global perspective and foster their international competitiveness. 2) It is essential to foster a collectivist spirit in the student. Students can appreciate the importance of teamwork and enhance their team collaboration skills by elaborating on the research and development journey of the domestic GIS software system. In addition, students can experience collectivism in practice, strengthening their sense of collective honor through methods such as group discussion and team collaboration. 3) It is imperative to strengthen the development of the scientific spirit and independent thinking capabilities of students. Within the regular teaching process, the emphasis must be placed on nurturing the scientific spirit of students by guiding them to respect facts, pursue truth, and show the courage to question and innovate. Synchronously, students' critical thinking skills should be stimulated through activities such as classroom discussions and case analysis, and their innovation awareness and problem-solving skills should be cultivated. 4) Environmental protection and sustainable development constitute essential ideological and political components. When instructing students in geography and spatial knowledge, it is crucial to steer them towards prioritizing environmental protection and sustainable development, thereby fostering a sense of social responsibility.

 

Table 1. Content of course-based ideological and political education and associated educational objectives

| Unit | Key points | Case study | Educational goals |
|---|---|---|---|
| Introduction | Concept of GIS<br>Development history of GIS<br>Composition, functions and applications of GIS | The history of the development of GIS shows that understanding things is a process. Things move on gradually, as does understanding and learning. | Cultivate a correct Marxist worldview and methodology |
| Geospatial and map projection | Space coordinates system<br>Geographic coordinate system<br>Principle of map projection<br>Principle and characteristics of Gauss projection | The necessity of punctuality in the conduct of affairs is illustrated by the case of the application of the coordinate system in real life.<br>The origin of the name Gauss projection is used to illustrate the scientific spirit. | Cultivate great professional ethics; Promote the scientific spirit |
| Acquisition of spatial data | Characteristics and classification of spatial data<br>Quality control of spatial data | The importance of nipping problems in the bud is illustrated by explaining the causes of spatial data quality errors and control methods.<br>High-resolution images were used as an example to introduce the development process of China's satellites. | Cultivate great professional ethics; Promote the patriotic spirit |
| Representation of spatial data | Types and representations of spatial data<br>Characteristics of vector data and raster data<br>Methods and principles of vector data compression | By integrating the use of real-world spatial data, it is shown that in practical applications it is crucial to analyze specific problems with a tailored approach. | Cultivate a correct Marxist worldview and methodology |
| Processing of spatial data | Structural transformation of spatial data<br>Establishment of topological relations<br>Vector data<br>Graphical editing<br>Cropping and splicing of graphics<br>Spatial data interpolation | The establishment of topological relationships and adherence to strict logical principles in vector data graph editing illustrate scientific rigor as a cornerstone to ensure the quality of results. | Cultivate great professional ethics; Promote the scientific spirit |
| Spatial database | Concept and development space of spatial databases<br>Design, establishment, maintenance and update of the database | Starting with data security as the entry point, data security issues and related laws and regulations are introduced during the course. | Establish a correct sense of professional ethics and legal awareness |
| Spatial data | Concepts and methods of | Using a specific Chinese city as a case | Cultivate a correct |

 

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|---|---|---|---|
| analysis | spatial analysis<br>Spatial measurement analysis and spatial statistical analysis<br>Overlay analysis<br>Buffer analysis<br>Digital elevation model analysis<br>Network analysis | study, ecological, economic and demographic data were integrated through a GIS-based multi-criteria evaluation to scientifically delineate regional ecological protection red lines. | Marxist worldview and methodology |
| Development and evaluation of GIS | Development process of GIS<br>Evaluation of GIS | Balancing the trade-off between development and conservation is paramount and embodies a holistic perspective on sustainable development. | Cultivate a correct Marxist worldview and methodology |
| Application examples of Land Information System | Application example of GIS | Spatial analysis bridges theory and practice. Through GIS, it optimizes public bicycle locations in cities, ensuring alignment with population density and POI needs. | Cultivate a correct Marxist worldview and methodology |
| 3s integrated technology | Introduction to Remote Sensing<br>Introduction to the Global Positioning System<br>Integration of GIS and RS<br>Integration of GIS and GPS<br>Significance of 3S integration | Introduce the development of China's Beidou positioning and navigation system (from GPS to GNSS), encourage students to constantly strive for scientific peaks, and enhance national pride. | Cultivate great professional ethics; Promote the patriotic spirit |

In conclusion, it is of paramount importance to enhance education in the areas of patriotism, collectivism, scientific spirit, independent thinking, environmental protection and sustainable development in order to develop GIS talents who are not only proficient in professional skills, but also endowed with high-minded qualities.

### *3.3 Innovations in assessment and feedback mechanisms*

#### *3.3.1 Develop a diversified assessment system*

This course has established a diversified evaluation system that integrates "theory-practice-innovative thinking", breaking through the limitations of traditional examinations and comprehensively assessing students' professional abilities and overall qualities. In terms of theory (accounting for 40% of the total grade), the evaluation system consists of two parts: examination scores (70%) and classroom performance (30%), with classroom performance mainly including attendance, homework, internship reports, and classroom discussions. The proportion of test scores in the current evaluation system is significantly reduced compared to the traditional single-test evaluation model. In the evaluation of practical abilities (accounting for 30% of the total grade), the course has designed 12 skill modules, including ArcGIS software operation assessment, remote sensing image interpretation experiments, and spatial database construction, to examine students' full-process practical abilities from data collection (30%), model construction (40%), to visualization expression (30%). In the aspect of cultivating innovative thinking (accounting for 30% of the total grade), the course has set up an "open proposition innovation track", encouraging students to propose innovative application plans related to national strategies such as rural revitalization and carbon neutrality based on GIS technology, and evaluating them from three dimensions: technical feasibility (50%), innovation (30%), and social value (20%). It can be seen that the course has developed a comprehensive and

 

multidimensional assessment system that aims to adequately reflect the overall qualities and abilities of students.

### *3.3.2 Timely feedback and adjustment of teaching strategies*

In the instructional innovation practice of this course, we establish dynamic teaching feedback and adjustment mechanisms, and use a diversified monitoring approach to capture the learning status of students in real-time. Specifically, we use the Superstar Learning instant feedback system to collect students' knowledge mastery, and combine learning analysis technology to quantitatively evaluate experimental operation data (such as ArcGIS software usage logs, spatial analysis assignment completion rates), and form personalized learning situation diagnosis reports every week. In response to problems identified in the feedback, we implement stratified intervention strategies: for students with weak foundations, adopt "one-on-one" tutoring; For advanced learners, stimulate the potential for innovation through open-ended project tasks. At the same time, teaching progress and methods are dynamically adjusted based on formative assessment data. For example, micro-lesson videos can be inserted to explain key steps in a timely manner when more than 70% of students experience difficulties in spatial analysis practice, or group mutual assistance learning can be organized. This "monitoring - feedback - intervention - optimization" closed-loop regulation mechanism can ensure that teaching strategies always keep pace with students' actual learning needs. The result of innovation practice has verified that classes adopting this model have significantly improved scores in spatial problem-solving ability tests ($p < 0.05$), and students' course satisfaction has reached 92.6%, effectively confirming the key role of timely feedback and strategy adjustment in improving the quality of GIS course teaching.

## 4. Teaching effectiveness and reflection

### *4.1 Teaching effectiveness*

Through innovative teaching practices, the teaching effectiveness of the "Principles of GIS" course has been significantly enhanced. In terms of knowledge acquisition, students can proficiently use ArcGIS software for spatial data analysis and visualization, and independently complete the modeling and solution of complex geographic problems. The course assessment data shows that the average scores and ratio of goal achievement of students has a consistent year-on-year improvement over the past three years (Figure 2), demonstrating a remarkable integration of theory and practice. In terms of ability development, after the implementation of project-based teaching, students' enthusiasm for participating in the "National College Students GIS Application Skills Competition" has increased. Their practical abilities in spatial analysis and programming development have been highly recognized by the judges, and the number and level of awards received by students has been increasing year by year. Regarding students' sense of social responsibility, the integration of ideological and political education in the course has led 91% of students to mention in course feedback that "it has enhanced their ecological civilization awareness in territorial space planning." Follow-up surveys of graduates show that the proportion of students engaged in GIS-related industries has been increasing year by year, and the evaluation results from employers are that "students have outstanding innovation capabilities in solving practical problems." These teaching achievements indicate that the innovative teaching reform of the "Principles of GIS" course has been successful.

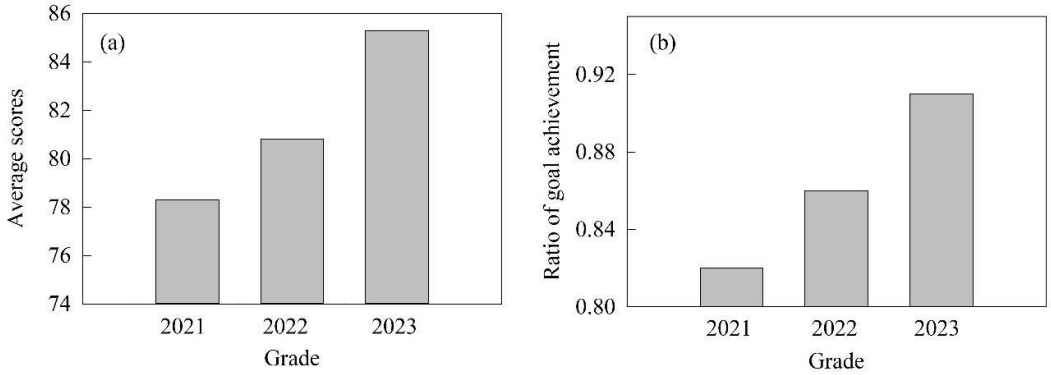


Figure 2. Average scores (a) and ratio of goal achievement (b) of students over the past three years

 

*4.2 Teaching reflection*

While the current teaching reforms have achieved phased results, there are still areas that need to be deepened. First, rapid technological iteration makes course updates more demanding. For example, integrated applications of AI and GIS have not been systematically incorporated into teaching content, and a dynamic textbook revision mechanism needs to be established. Second, the implementation of hierarchical teaching is inadequate. Participation in project-based learning is low among some students with weak foundations. In the future, it is planned to add pre-class skills mini-lessons and graded practical tasks. Third, there is a need to improve collaborative education between schools and businesses. Currently, the enterprise case library only covers land and environment, and there is a need to expand cooperation and development in emerging application scenarios such as smart cities and public health.

The following three aspects are planned to be improved in future. 1) It is to build a "technology tracking - teaching transformation" dual circulation system, and regularly invite industry experts to participate in the revision of the course syllabus. 2) An adaptive learning system is developed to enable personalized tutoring through student situation diagnosis. 3) We will deepen the integration of industry and education, strengthen communication and cooperation with local enterprises, and incorporate real-world projects into curriculum design. In the future, the focus will be on strengthening the closed-loop implementation of the OBE concept to ensure that talent development is precisely aligned with industrial requirements.

## 5. Conclusion

Innovative teaching is an essential way to improve the quality of teaching and to develop practical ability and an innovative spirit in students. This paper takes the "Principles of GIS" course as an example, and conducts teaching innovation practice and exploration through innovative teaching methods, innovative teaching contents, and innovative evaluation and feedback mechanisms. At the same time, it presents some achievements since the implementation of the innovative practice. These teaching achievements indicate that the innovative teaching reform of the "Principles of GIS" course has been successful. In the future, it is necessary to continue to strengthen innovative teaching practices and exploration to further improve the quality of student cultivation and bring it more in line with the needs of modern social development.

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