Digital Intelligence Empowerment for Dual-Dimensional Driving: Synergistic Advancement Mechanism of Human Settlement Governance Practice and Modular Teaching Innovation of Environmental Design Curricula

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ABSTRACT

Under the dual strategies of Digital China and Rural Revitalization, the intelligent transformation of human settlement governance and the adaptive reform of environmental design education exhibit deeply integrated needs. This study proposes a "Dual-Dimensional Driving" synergistic model, with the core logic of leveraging governance practices to feed back into teaching resource development and using pedagogical innovation to support the implementation of governance technologies. It constructs a four-dimensional pathway encompassing "Target Synergy, Content Restructuring, Platform Interconnection, and Evaluation Closed-loop." By analyzing reform cases of environmental design programs in applied universities in Shandong Province and integrating scenario-based applications of Internet of Things (IoT), GIS, and AIGC technologies in rural governance, this study demonstrates the effectiveness of modular courses in cultivating interdisciplinary talents proficient in "technology, governance, and design." It provides a systematic solution for empowering sustainable development through industry-education collaboration.

Keywords: Digital Intelligence Empowerment; Human Settlement Governance; Environmental Design Education; Modular Teaching; Industry-Education Collaboration; Dual-Dimensional Driving

1 Introduction: Inevitcompetency of Era of Dual-Dimensional Driving

Under the wave of digital China and rural revitalization strategies, the intergration needs of intelligent transformation of human settlement governance and environmental design education reform is increasingly prominent. The construction of digital China emphasizes the promotion of innovation and development in various fields with digital and intelligent technologies, while the rural revitalization strategy focuses on the all-round development of rural areas, in which the governance of human settlement is the key link. Intelligent transformation can improve the efficiency and quality of governance and improve the living environment of rural residents, while the reform of environmental design education provides a guarantee for cultivating professionals who meet the needs of the new era. They are interdependent and promote each other, and jointly promote the sustainable development of rural human settlement.

However, the current governance and education all face some common challenges. In the governance, there are problems of data fragmentation and response lag. The sensor coverage in rural areas is insufficient, which leads to incomplete data collection and makes it difficult to make effective data analysis and decision. At the same time, the lack of coordination among the government, enterprises and villagers makes it difficult to form a joint force in governance. In the educational dimension, there

are some problems in the course of environmental design, such as the disconnection of knowledge system and the blurring of practical links. The content of the course lacks cutting-edge knowledge such as wisdom and sanitation, practical topics are divorced from real scenes, and the evaluation mechanism is single, which cannot meet the needs of practical work.

As a dual-dimensional link, digital intelligence technology provides theoretical logic for solving these problems. Through digital intelligence technology, real-time data collection, analysis and sharing can be realized, and the situation of data fragmentation can be broken. At the same time, the use of digital intelligence technology can build an intelligent governance platform to improve response speed and collaborative efficiency. In education, digital intelligence technology can be embedded in the course content, so that students can get in touch with cutting-edge knowledge and practical cases and enhance their practical competency.

Based on this, it is of great significance to establish a closed-loop upgrading framework of "practice-education-re-practice". In this framework, practice provides real scenes and needs for education, education cultivates professionals for practice, and re-practice tests and improves the effect of education. Through continuous circulation, the coordinated development of human settlement governance and environmental design education will be realized.

Specifically, in practice, the data of rural human settlement governance is collected through digital intelligence technology, and the pain points and needs of governance are analyzed. In education, the course and teaching content should be adjusted according to practical needs to cultivate students' competency to solve practical problems. In the re-practice, the students' knowledge is applied to actual governance, and the educational content and methods are further optimized through practical feedback.

In short, under the background of digital China and rural revitalization strategies, there is an urgent need to couple the intelligent transformation of human settlement governance with the reform of environmental design education. By solving the common challenges of governance and education, the closed-loop upgrading framework of "practice-education-re-practice" is established by using digital intelligence technology, which can realize the coordinated development driven by two dimensions and provide strong support for the improvement and sustainable development of rural human settlement.

2 Analysis of the Present Situation: Mismatches and Opportunities of Governance Needs and Teaching Reform

2.1 Digital Intelligence Bottlenecks in Governance Practice

The governance of rural human settlement faces many technical bottlenecks in the process of digitalization. Firstly, the coverage rate of rural sensors is low. Due to the limitation of funds and technology, environmental monitoring sensors cannot be fully laid in most rural areas, which leads to the incompetency to collect environmental data in real time and accurately. For example, in the aspect of garbage disposal, there is a lack of real-time monitoring of the overflow of garbage cans, which makes the garbage cleaning not timely and affects the rural sanitation environment. At the same time, the lack of data analysis is also a big shortcoming. Even if some data are collected, due to the lack of professional analysis competency and tools, it is difficult to mine valuable information from the data and formulate scientific and effective governance strategies, as shown in Table 1-1.

There are obvious gaps between these weak technical problems and teaching courses. At present, in the courses of environmental design specialty, there are few intelligent contents such as sensor technology and data analysis, and students lack relevant knowledge and skills, so it is difficult to meet the needs of actual governance work.

In addition, the lack of coordination among the government, enterprises and villagers is also prominent. The following is a comparative table of specific manifestations and teaching relevance, such as Table 1-2:

Table 1-1

Problem Type	Specific Manifestations	Educational Gap
Weak Technical Application	Rural sensor coverage <30%, lack of data analysis	Courses lack IoT/GIS operation training modules
Insufficient Stakeholder Coordination	Fragmented participation among government, enterprises, and villagers	Teaching design neglects multi-party collaboration skills cultivation

2.2 Lag in Environmental Design Curricula

At present, there is a serious lag in environmental design curricula, which is mainly reflected in two aspects: the disconnection of knowledge system and the blurring of practical links. In terms of knowledge system, the course content lacks cutting-edge contents such as smart sanitation and intelligent facility design. Taking smart sanitation as an example, with the development of science and technology, smart trash cans and intelligent garbage sorting systems have been applied in some cities, but they are rarely involved in environmental design curriculas. After graduation, students enter practical jobs, knowing nothing about these new technologies and new equipment, and can't meet the job requirements.

The blurring of practical links is also a prominent problem. Many practical projects are divorced from the real scene, and students only design in a simulated environment, lacking in-depth understanding and solving competency of practical problems. For example, an environmental design curricula in a university simulates a rural environmental design project, but the data and scenes in the project are fictitious, which is far from the actual rural situation. The design scheme completed by students can not be implemented in practical application at all.

In addition, the single evaluation mechanism is also a drawback of environmental design curricula. At present, the evaluation is mainly based on teachers' subjective evaluation, lacking objective quantitative indicators and diversified evaluation methods. For example, when a school evaluates students' design works, it only pays attention to the aesthetics of the works and ignores its functionality and practicality, which leads students to pursue form too much and ignore the actual needs.

Table 1-2

Subject	Specific Manifestations	Educational Relevance
Government	Insufficient policy guidance and funding for digital governance; lack of unified planning and coordination	Courses lack content on policy interpretation and project planning
Enterprises	Low enthusiasm for participating in rural governance; limited technological R&D and application capabilities	Students lack opportunities for practical collaboration with enterprises and insufficient understanding of enterprise technologies and operational models
Villagers	Low awareness and participation in digital governance; lack of environmental awareness and responsibility	Courses lack content on public participation and environmental education

3 Research on Synergistic Advancement Pathways: Four-dimensional Mechanism of Dual-dimensional Fusion

3.1 Goal Alignment: Construction of Demand-oriented Competency Matrix

The "governance pain points → competency goals → course modules" transformation model is a strategic approach to bridge the gap between human settlement governance needs and environmental design education. The model takes the pain points in governance practice as the starting point, defines the required competency goals, and then transforms these competency goals into specific course modules.

Taking intelligent garbage classification and river pollution tracecompetency as examples, the governance pain point of intelligent garbage classification lies in the villagers' lack of classification awareness and low classification accuracy. The corresponding competency goals include understanding the principle and operation of intelligent classification equipment, mastering data analysis to optimize classification strategy and so on. These competency objectives can be mapped to the course modules such as intelligent facility design and data-driven planning. These competency objectives can be mapped to the course modules such as intelligent facility design and data-driven planning. The pain point of river pollution tracecompetency is that the pollution source is difficult to determine and the control measures are not targeted. The competency goal covers mastering water quality monitoring technology, using GIS analysis to determine the location of pollution sources, etc., which can correspond to data-driven planning, collaborative governance design and other course modules.

The participation mechanism of enterprise tutors is also an important part of goal coordination. Enterprise tutors have rich practical experience and can bring practical cases and industry needs into the classroom. They can participate in the curricula design to ensure that the course content is closely integrated with the actual work; It can also guide students to practice projects and help them better master practical skills.

3.2 Reconstruction of Content: Construction of "Technology Chain-Scenario" - Based Course Clusters

Constructing modular course comparison table is the core of content reconstruction. See Table 1-3 for details:

In the course of intelligent facility design, sensor technology is used to monitor the status of facilities in real time, and the Internet of Things application realizes data transmission and sharing, and intelligent control

Table 1-3

Module Type	Core Course	Technology Embedding Points	Practice Carrier
Intelligent Facility Design	Smart Facilities and Low-Carbon Materials	Solar Sensors, Biomass Power Supply Systems	Rural Waste Sorting Pavilion Design
Data-Driven Planning	GIS Spatial Analysis and Environmental Simulation	Pollution Heatmap Generation, Solution Simulation Optimization	River Ecological Restoration Digital Twin Project
Collaborative Governance Design	Community Participatory Design Methodology	Blockchain Consensus Mechanisms, Villager Feedback APP	Multi-Party Collaboration Platform for Village Appearance Improvement

algorithm can automatically adjust the operation of facilities according to the data. The practical carrier can be to design an intelligent trash can, monitor the overflow of garbage through sensors, and transmit data to the governance platform by using the Internet of Things to realize intelligent cleaning and scheduling.

In the course of data-driven planning, GIS analysis can be used to analyze geospatial data, and big data mining and machine learning algorithms can be used to predict trends and find potential problems. The practical project can be to plan rural land use, and make a reasonable planning scheme by analyzing historical data and current situation information.

In the course of collaborative governance design, the application of blockchain can ensure the security and non-tampering of data, and multi-agent collaborative technology promotes effective communication and cooperation among government, enterprises and villagers. The practical project can be a rural environmental governance project, and all parties participate in decision-making and implementation through the blockchain collaborative governance platform.

The 2024 Digital Intelligence Empowerment Conference put forward some frontier directions, such as AIGC aided design and digital twin technology. These cutting-edge technologies can be integrated into the course clusters, so that students can be exposed to the latest industry trends and technology applications.

3.3 Platform Interconnection: Framework of Industry - Education Integration Lab

The framework of industry-education integration laboratory mainly includes data sharing platform, technical training platform and blockchain collaborative governance platform.

The data sharing platform can call the real governance database to provide students with rich actual data. These data include rural environmental monitoring data, garbage disposal data and river water quality data. Students can use these data for analysis and research to improve their ability to solve practical problems.

The technical training platform is equipped with VR simulation and IOT suite. VR simulation can simulate the real rural environment and governance scenes, allowing students to practice in the virtual environment. The Internet of Things suite allows students to experience the installation and debugging of sensors and smart devices and master the application of Internet of Things technology.

The blockchain collaborative governance platform is used to realize information sharing and collaborative governance among governments, enterprises and universities. All parties can publish project information, share data and conduct cooperation and exchanges on the platform. Ensure the security and credibility of data through blockchain technology.

School-enterprise co-construction mode is an important way to build a industry-education integration laboratory. Enterprises provide funds, equipment and practical projects, while universities provide teachers and teaching resources. The two sides jointly formulate the laboratory construction plan and teaching plan to realize resource sharing and complementary advantages. The incubation pathway of results includes transforming students' design works and research results into actual products or solutions, and promoting and applying them through the market channels of enterprises.

3.4 Evaluation Closed - Loop: Dual - Dimensional Efficacy Dynamic Tracking

Establishing multi-source teaching evaluation system is the main content of evaluation closed loop. AI correction can quickly and objectively evaluate students' homework and design works, and improve the efficiency and accuracy of evaluation. The survey of villagers' satisfaction can understand the improvement effect of students' design works and practical projects on the actual rural environment. In addition, enterprise tutors and industry experts can also be invited to evaluate students' performance, and comprehensively evaluate students' learning achievements by synthesizing opinions from various aspects.

Governance efficacy tracking mechanism is measured by quantitative indicators. Specific quantitative indicators are shown in Table 1-4:

Table 1-4

Indicator Type	Specific Indicators
Facility Utilization Rate	Smart Trash Bin Utilization Rate, Smart Street Light Activation Rate, etc.
Pollution Reduction	Reduction in Waste Discharge, Reduction in River Pollutants, etc.
Governance Cost Reduction Rate	Reduction Rate in Waste Treatment Costs, Reduction Rate in Environmental Monitoring Costs, etc.

Through the dynamic tracking of these indicators, we can know the governance effect in time, find problems and adjust the teaching content and governance strategies in time. These indicators can also be used as an important basis for evaluating teaching quality and governance efficiency.

4 Practical Validation: An In-depth Analysis of the Reform Cases of Colleges and Universities in Shandong Province

4.1 Industry-college-institute Cooperation Integration Framework

Yantai Nanshan University has built an industry-college-institute integration framework in the synergistic advancement of human settlement governance and environmental design education, and achieved remarkable results.

Teacher restructuring is an important foundation of this framework. The university adopts a "double-professionally-titled teachers+engineers" model. Double-professionally-titled teachers possess both solid theoretical knowledge and rich practical experience, and are able to combine academic knowledge with practical application in teaching. Engineers come from the front line of enterprises and bring the latest technology and practical cases in the industry. For example, in the course of intelligent facility design, engineers will combine practical projects to explain the installation and debugging points of intelligent sensors to students, so that students can better master practical operational skills.

Technological empowerment is the key to improving governance efficiency. The university has introduced drone 3D modeling technology, which has played an important role in rural planning and environmental monitoring. By using drones for 3D modeling, it is possible to quickly and accurately obtain information on rural terrain, topography, and environment, providing detailed data support for planning and design. Meanwhile, this technology also saves fuel consumption, with statistics showing a 23% reduction in fuel consumption compared to traditional measurement methods. This not only reduces costs, but also improves work efficiency.

The patent conversion results have significantly improved the efficiency of garbage disposal. The intelligent garbage disposal scheduling system developed by the university has obtained a patent and has been applied in practical projects. The system improves the efficiency of garbage collection by 35% by monitoring the overflow situation of garbage bins in real time and planning the transportation route reasonably. This achievement not only solves the problem of untimely garbage cleaning, but also reduces the waste of manpower and material resources.

On the docking mode of course and local needs, the university thoroughly investigates the actual needs of local villages and adjusts the course content and practice projects according to the needs. For example, in order to solve the problem of local rural garbage disposal, courses related to intelligent garbage classification and removal were set up, and students were organized to participate in

practical projects. Through this docking mode, students' knowledge can be directly applied to practical work, which improves students' employment competitiveness and provides strong support for the governance of local rural human settlement.

4.2 Industry Collaborative Innovation Mechanism

The 2024 Digital Intelligence Empowerment Conference has brought new technology introduction and innovation opportunities to Yantai Nanshan University. The transformation of topics such as AIGC-aided design put forward by the conference has been actively introduced into teaching and practice by the university. In the environmental design curricula, students begin to learn to use AIGC technology to generate and optimize design schemes. By inputting relevant parameters and requirements, AIGC can quickly generate a variety of design schemes and provide more creative inspiration for students. At the same time, digital twin technology has also been applied to rural environment simulation and planning, so that students can understand the implementation effect of the design scheme more intuitively.

In terms of cross-domain collaboration, the university participated in the establishment of the Digital Intelligence Human Settlement Environment Alliance. The alliance brings together the government, enterprises, universities and other forces to jointly promote the intelligent development of rural human settlement governance through resource sharing and technical cooperation. With the support of the alliance, the university and enterprises have carried out a number of cooperative projects, such as the research and development and application of intelligent facilities, data-driven rural planning and so on.

The tripartite cooperation case of government-enterprise-university is also very typical. In a rural environmental governance project, the government provides policy support and financial guarantee, enterprises are responsible for technology research and development and project implementation, and universities provide talents and technical support. The three parties communicate and collaborate through the blockchain collaborative governance platform to ensure the smooth progress of the project. This tripartite cooperation model gives full play to the advantages of all parties, realizes the optimal allocation of resources, and provides an effective solution for the governance of rural human settlement.

5 Implementation Safeguards: Triangular Support of System, Technology and Resources

5.1 Institutional Innovation Breakthroughs

In order to promote the coordinated development of human settlement governance and environmental design education, institutional innovation is the key. The design of professional certification standard for "smart rural designers" is an important breakthrough. The standard should cover professional knowledge, practical skills, innovation ability and other dimensions. In terms of professional knowledge, designers are required to master cutting-edge knowledge such as smart sanitation and intelligent facility design; In terms of practical skills, it is necessary to have the ability to solve practical problems by using GIS analysis, blockchain application and other technologies. By setting strict certification standards, we ensure that employees have high-quality professionalism.

The entrepreneurship incentives are also essential. The government and universities can jointly set up a special fund to provide financial support for students and teachers engaged in entrepreneurial projects related to rural human settlement governance, and provide venues, equipment and other resources to lower the threshold for entrepreneurship. For example, set up an entrepreneurship base to provide entrepreneurs with office space and experimental equipment.

A cross-departmental collaboration framework is equally important. The education department and the Ecological Environment Bureau should establish a linkage mechanism to jointly formulate talent training programs and governance policies. The education department adjusts the curriculum according to the needs of the Ecological Environment Bureau, which provides students with practical opportunities and data support. Through this cross-departmental collaboration, education and governance can be seamlessly connected.

5.2 Technology Adaptation Strategies

Technical adaptation is the core of ensuring coordinated advancement. Developing lightweight tools is the key measure. The application of mobile GIS has the characteristics of convenience and real-time, which allows staff to quickly obtain geospatial data on site for analysis and decision-making. For example, in rural planning, through the application of mobile GIS, staff can view the topography and land use in real time and adjust the planning scheme in time.

The construction of open - source module libraries is also very important. Develop sensor interface standards to make sensors from different manufacturers compatible and interoperable. This can reduce the development cost and improve the stability and reliability of the system. For example, in the design of intelligent facilities, a unified sensor interface standard can make all kinds of intelligent sensors easily integrated into the system.

Reducing the hardware cost is also an important aspect of technology adaptation. Lease and sharing modes can be adopted to reduce the procurement cost of hardware equipment. At the same time, promote the use of low-cost, high-performance hardware devices, such as low-power sensors and miniaturized servers.

5.3 Resource Integration Pathways

Resource integration is an important guarantee for synergistic advancement. In terms of financial support, enterprise - sponsored labs is an effective way. Enterprises provide funds and equipment support for universities through sponsoring laboratories, while universities train professionals and carry out scientific research cooperation for enterprises. For example, an enterprise sponsored the environmental design laboratory of a university, which provided the laboratory with advanced experimental equipment and scientific research funds, and at the same time, the university trained a group of professionals to meet the needs of the enterprise.

In terms of infrastructure security, rural 5G coverage is crucial. The high-speed and stable transmission of 5G network can support real-time data transmission and remote control of intelligent facilities. For example, in the application of smart trash cans, the 5G network can ensure that the garbage overflow information is transmitted to the governance platform in time and accurately, and realize intelligent cleaning and scheduling.

The priority policy of resource allocation also needs to be clear. Priority should be given to projects and courses closely related to the treatment of pain points. For example, for key issues such as intelligent garbage classification and river pollution traceability, priority should be given to allocating funds and equipment to ensure the smooth implementation of the project. At the same time, according to the importance and urgency of the project, resources should be arranged reasonably to improve the efficiency of resource utilization.

6 Conclusion and Prospects

6.1 Summary of Essence of Dual - Dimensional Driving

The dual-dimensional driving of the integration of education chain and governance chain is essentially to build a bridge between the practice of human settlement governance and environmental design education through digital intelligence technology, forming a closed-loop upgrading framework of "practice-education-re-practice". In this framework, governance practice provides real scenes and needs for education, and promotes the continuous reform of education to cultivate professionals who are suitable for practical work; The talents trained by education apply their knowledge to governance practice, promote the improvement of governance level, and then feed back to education to realize the coordinated development of the two.

Digital intelligence technology plays a core role in it. It breaks the problems of data fragmentation and response lag in the governance dimension, as well as the disconnection of knowledge system and the blurring of practical links in the education dimension. Through real-time data collection, analysis and sharing, digital intelligence technology makes the governance work more scientific and efficient, and at the same time makes the educational content more suitable for the actual needs, so that students can get in touch with cutting-edge technologies and real cases and enhance their practical

ability.

6.2 Value of Three - Dimensional Competency Cultivation

It is of great value to cultivate the three-dimensional competency of "technology application+system design+public policy". In terms of technology application, students master cutting-edge technologies such as smart sanitation, intelligent facility design, GIS analysis and blockchain application, which can be directly applied to the practice of human settlement governance. For example, intelligent facility design technology can improve the intelligent level of rural infrastructure, and GIS analysis technology is helpful for rural planning and environmental monitoring. The application of these technologies has improved the efficiency and quality of governance and solved the technical problems in practical work.

Cultivating students' ability of system design makes them treat the human settlement governance from a holistic perspective. Students need to comprehensively consider various factors, such as the needs of the government, enterprises and villagers, and the synergy between different technologies to design a scientific and reasonable governance plan. For example, in collaborative governance design, students should use multi-agent collaborative technology and blockchain application to build a system architecture of government-enterprise-villagers collaborative governance to achieve effective communication and cooperation among all parties.

Public policy competency enables students to understand the background and objectives of policy formulation, and can integrate policy requirements into design and practice. The education department cooperates with the bureau of ecology and environment and other departments to make students understand the close relationship between policy and practical work. In the learning process, students can adjust the design scheme according to the policy orientation, ensure that the project meets the policy requirements, and promote the smooth development of governance work.

6.3 Prospect of Deepening Direction

(1) Scenario - Specific Course Differentiation

Future environmental design curricula can be differentiated according to different scenarios, such as rural and suburban customized modules. The rural module can focus on the human settlement governance with rural characteristics, such as intelligent garbage classification, river pollution traceability, rural planning. The course content can be combined with the actual situation in rural areas, such as topography and cultural characteristics, to cultivate students' ability to solve practical problems in rural areas. Suburban module can pay attention to the characteristics of urban-rural transition zone, such as population flow and land use change, and design corresponding course content, such as suburban ecological restoration and urban fringe planning.

(2) Credit Bank System

The introduction of credit bank system can promote students' autonomous learning and lifelong learning. Credits earned by students in different learning stages and institutions can be deposited in credit banks and exchanged and converted when necessary. For example, the practical credits obtained by students in enterprise internships can be converted into course credits of schools, or credits can be recognized among different universities. This can break the time and space constraints of learning and improve students' learning enthusiasm and flexibility.

(3) Metaverse - Enabled Collaboration

Metaverse technology has brought new opportunities for environmental design education and human settlement governance. In education, metaverse can provide a more realistic virtual practice scene, so that students can design and operate in the virtual environment and improve their practical ability. For example, students can design a virtual rural environment in metaverse, interact and communicate with other students and tutors, and jointly improve the design scheme. In terms of governance, metaverse can realize long-distance cooperation and real-time communication among many parties. Government, enterprises and villagers can participate in governance decision-making together in metaverse, so as to improve governance efficiency and coordination. For example, in rural planning projects, all parties can discuss and modify

the scheme in real time in metaverse, which avoids the time and space limitations of traditional communication methods.

To sum up, by summarizing the essence of dual-dimensional driving and refining the value of three-dimensional competency training, and looking forward to the deepening direction of scenario - specific course differentiation, credit bank system and metaverse cooperation, the synergistic development of human settlement governance and environmental design education will usher in a broader prospect and provide more powerful support for the improvement and sustainable development of rural human settlement.

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