Frontiers in Educational Innovation and Research
http://dx.doi.org/10.62762/FEIR.2025.323427

RESEARCH ARTICLE

Reconstruction of Data Structures Course Teaching Model for Smart Agriculture Talent Cultivation: Integrated Practice of Value Shaping and Capability Development

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Abstract

In response to the current imbalance phenomenon of "emphasizing skills while neglecting values" in programming practice teaching oriented toward smart agriculture, this study employs the Data Structures course as a vehicle. It applies Checkland's Soft Systems Methodology (SSM) to construct a three-dimensional integrated teaching objective system of "knowledge transfer–capability cultivation–value shaping." Through systematic reconstruction of seven teaching modules centered on linear lists, trees, graphs, sorting, and searching, the teaching objectives are transformed from mere knowledge acquisition to an organic integration of knowledge, capability, and value objectives. In the value dimension, the teaching scheme emphasizes integrating core value elements oriented toward smart agriculture, including systematic engineering decision-making, data security and privacy protection, resource conservation and efficiency optimization, and rigorous professional ethics and compliance spirit. Statistical analysis of controlled experiments conducted over two rounds with 350 students demonstrates that the experimental group achieved improved average scores ($p < 0.05$) with more concentrated grade distribution and notably reduced standard deviation. This study provides an operational reform pathway for the deep integration of professional and value education in smart agriculture-related courses.

Keywords: smart agriculture, soft systems methodology, three-dimensional teaching objectives, value-integrated teaching.

1 Introduction

The wave of global digital transformation is profoundly reshaping the landscape of higher education, with programming education having become an indispensable component in cultivating innovative engineering talents across relevant disciplines in universities [1]. Against the backdrop of new engineering education initiatives, society has put forward increasingly diversified requirements

Submitted: 24 October 2025
Accepted: 02 November 2025
Published: 29 December 2025

Vol. 1, **No.** 3, 2025.
10.62762/FEIR.2025.323427

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Citation
Yi, W., Chen, J., & Weng, L. (2025). Reconstruction of Data Structures Course Teaching Model for Smart Agriculture Talent Cultivation: Integrated Practice of Value Shaping and Capability Development. *Frontiers in Educational Innovation and Research*, 1(3), 100–109.

for talent cultivation in interdisciplinary fields of digital technology—requiring not only solid professional skills as a foundation, but also the support of comprehensive competencies such as innovative consciousness, teamwork spirit, and social responsibility [2, 3]. Compared to traditional computer science education, smart agriculture talent cultivation requires transforming the learning of data structures and algorithms from a pure pursuit of technical efficiency to the comprehensive development of systems thinking, rule compliance, and value judgment, considering the characteristics of complex agricultural scenarios, resource constraints, and ethical sensitivity. Values-integrated teaching has emerged as an innovative educational model that deeply explores the value elements embedded in courses, organically integrates them with professional knowledge, and achieves the organic unity of knowledge transmission, capability cultivation, and character development [4, 5]. This teaching model is receiving increasing attention in global higher education reform and is regarded as an important pathway for cultivating interdisciplinary talents with international competitiveness [6, 7].

However, programming practice teaching in data structures at universities faces the common problem of "emphasizing skills while neglecting values" [8], making it challenging to meet the cultivation needs for interdisciplinary talents in smart agriculture. The core challenge stems from the transformation from macro-level guidance to micro-level implementation: while frameworks such as ABET [9] and the Washington Accord [10] clearly define ethical and social responsibility requirements at the top level, how to translate these into concrete and operational pathways oriented toward agricultural application scenarios in teaching practice remains to be explored in depth. Traditional task-driven teaching models overemphasize technical implementation while neglecting the cultivation of students' critical thinking and innovative capabilities [11]. Under such teaching environments, students mechanically complete programming tasks and lack deep thinking about the essence of new problems in the agricultural domain. Current course content lags significantly behind the pace of technological development, with verification-oriented content occupying excessive teaching time, making it challenging to stimulate students' learning interest and initiative [12]. For example, in the teaching of foundational courses such as data structures, the explanation of conceptual knowledge points is often isolated from actual application scenarios in smart agriculture, making it difficult for students to apply their knowledge to solve practical agricultural problems. Furthermore, forcibly incorporating values education content may trigger students' resistance and affect overall teaching effectiveness. How to naturally integrate values education without compromising the quality of professional teaching has become a significant challenge facing current teaching reform.

To address the aforementioned issues, recent research has mainly concentrated on enhancing students' professional capabilities through innovative methods such as problem-based learning and blended teaching, and exploring integration pathways of value elements with professional knowledge [13]. However, such research primarily focuses on theoretical course teaching, with insufficient attention to value integration in practice teaching oriented toward specific domains such as smart agriculture.

Therefore, this study aims to explore and construct a data structures course teaching model oriented toward cultivating smart agriculture talent, in order to address the dilemma of imbalance between character development and capability cultivation in programming practice teaching. Taking the "Data Structures" course as a specific vehicle, this research endeavors to organically integrate value-guiding elements into programming practice for smart agricultural technology applications through systematic teaching reconstruction, providing an implementable and scalable solution for achieving deep integration of professional education and values education.

2 Materials and Methods

2.1 Teaching Objective System Design Based on Checkland's Soft Systems Methodology

This study adopts Checkland's Soft Systems Methodology (SSM) to systematically construct a three-dimensional teaching objective system for the Data Structures course oriented toward smart agriculture talent cultivation. SSM emphasizes holistically understanding complex human activity systems and is particularly suitable for addressing unstructured problems such as integrating technology and values in agricultural engineering education [14]. Following SSM's iterative learning process, the study identified the disconnection problem between skill cultivation and value shaping in programming

Table 1. Integration design of value-leading elements and knowledge points in data structures course.

Teaching Module	Knowledge Points	Value Elements
Introduction	Basic concepts of data and data structures; concepts and performance evaluation of algorithms, etc.	**Innovative Spirit:** Through evaluating the performance and applicable scenarios of different data structures in agricultural data analysis tasks, cultivate students to become rational innovators who understand trade-offs and are good at making choices.
Linear List	Concepts of linear lists, abstract data types, insertion and deletion algorithms for sequential storage structures, etc.	**Critical Thinking and Systematic Thinking:** Analyze the impact of insertion/deletion operations in sequential storage on overall efficiency in agricultural data batch processing, understand the dialectical relationship between local operations and global performance, and learn to make trade-offs in engineering decisions.
Stack and Queue	Concepts, characteristics, storage structures, and basic operations of stacks and queues.	**Rule Consciousness and Rigor: Understand that stacks** (LIFO) and queues (FIFO) are "contracts" that must be followed in agricultural intelligent equipment coordination and task scheduling, cultivating a work style of protocol compliance and rigorous conduct in complex agricultural systems.
Tree and Binary Tree	Definition and basic terminology of trees; definition, properties, and storage structures of binary trees, etc.	**Logical Rigor and Information Ethics:** Through tree structures, understand hierarchical management and access control of agricultural information, emphasizing professional ethics of protecting privacy, maintaining data security and integrity in agricultural data processing.
Graph	Abstract data types of graphs; storage structures of graphs; depth/breadth-first search; connected components, etc.	**Collaborative Spirit and Global Perspective:** View graph structures as complex networks composed of agricultural IoT nodes or production units, emphasizing connections and collaboration between individuals (vertices), cultivating perseverance and team awareness in solving complex agricultural system problems.
Sorting	Basic concepts, classification, and importance of sorting; principles and implementation of various classical sorting algorithms, etc.	**Efficiency Concept and Optimization Spirit:** Through comparing the performance of different sorting algorithms in agricultural real-time data processing, deeply understand the concept of time and space as precious computational resources, cultivating professional spirit of pursuing efficiency and relentless optimization in agricultural engineering practice.
Search	Basic concepts of searching; sequential search, binary search, and indexed sequential search, etc.	**Craftsmanship Spirit of Excellence Pursuit:** From inefficient sequential search to efficient binary search, reflecting the ultimate and uncompromising pursuit of agricultural big data retrieval performance, internalizing this attitude of excellence pursuit as core professional character.

teaching. It defined the Data Structures course as a transformation system for cultivating compound talents with professional capabilities and social responsibility in the smart agriculture domain.

Through CATWOE analysis of the SSM methodology [15], this study identified key elements of the teaching system and constructed a three-dimensional teaching objective gear model as shown in Figure 1. This model designs knowledge, capability, and value objectives as three interlocking gears, embodying the holistic and dynamic characteristics of the educational system. Knowledge objectives encompass fundamental theories and core algorithms, capability objectives focus on practical application and problem-solving, and value objectives emphasize thinking consciousness, professional ethics, and social responsibility. The three dimensions achieve coordinated development through the gear meshing mechanism, where the rotation of any dimension drives synergistic progress in the other dimensions.

2.2 Course Content Reconstruction Oriented Toward Value Leadership

Applying SSM's conceptual model construction method, this study views course content reconstruction as a purposeful activity system. Three content selection principles were established by comparing the gap between actual teaching and the ideal model: representativeness of knowledge points, compatibility of value elements, and naturalness of integration methods. Table 1 presents the value

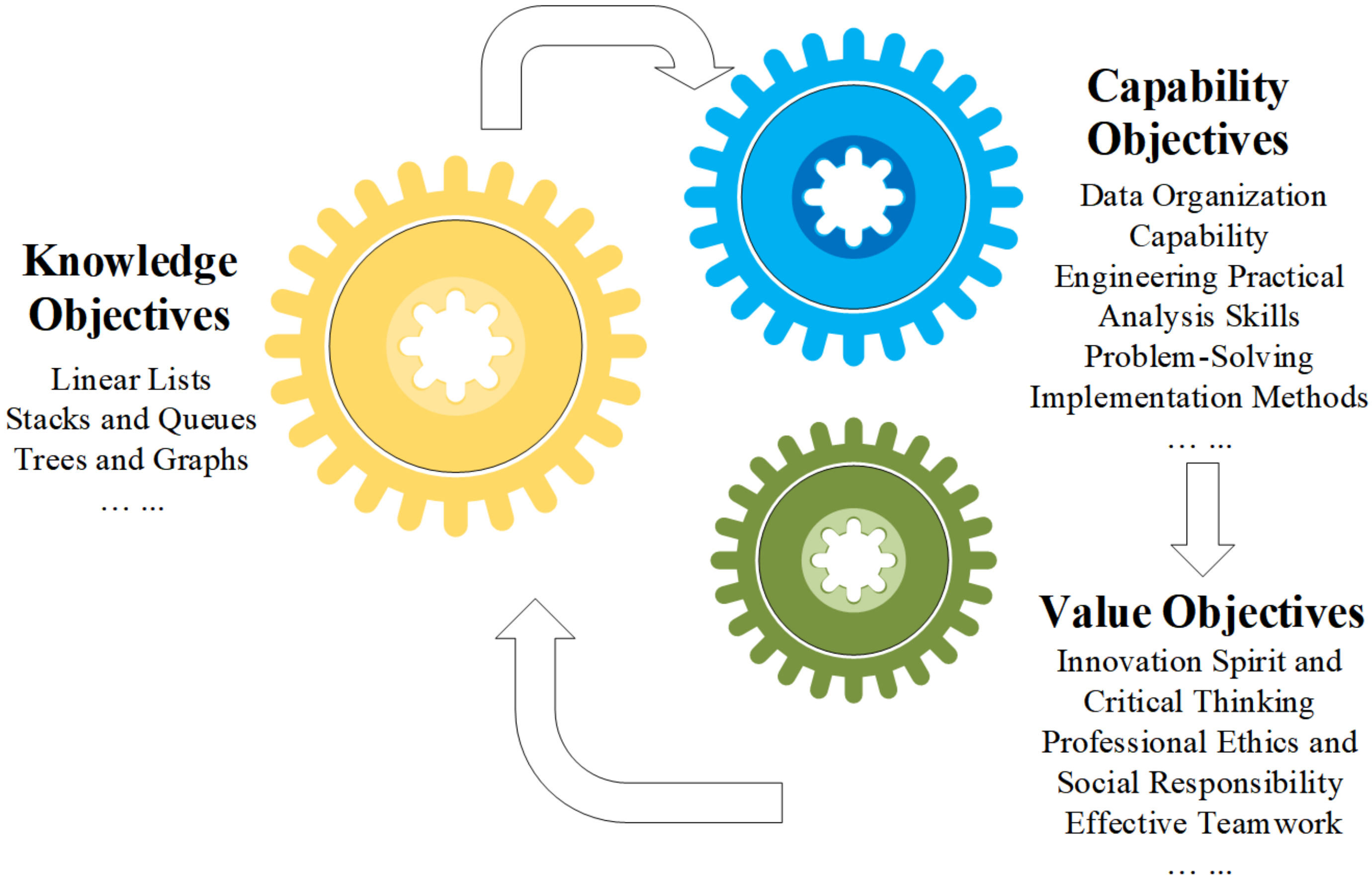

Figure 1. Three-dimensional integrated teaching objective system.

integration scheme for seven modules based on these principles.

The introduction module cultivates innovative spirit and rational selection capabilities through algorithm performance evaluation [16]; the linear list emphasizes critical thinking, understanding the dialectical relationship between local operations and global efficiency [17]; stack and queue highlight rule consciousness, viewing LIFO/FIFO principles as manifestations of contractual spirit [18]; tree structure integrates information ethics, introducing data privacy protection awareness through hierarchical relationships [19]; graph structure analogizes social networks, cultivating collaborative spirit and global perspective [20]; sorting algorithms establish efficiency concepts, understanding the preciousness of computational resources [21]; search algorithms embody craftsmanship spirit, pursuing ultimate optimization of algorithm performance [22].

2.3 Teaching Strategy Framework Design

The teaching strategy framework constructed in this study adopts a "three-level linkage, three-objective orientation" design architecture, systematically integrating the Data Structures knowledge system, teaching method innovation, and value element integration. As shown in Figure 2, this framework breaks through the traditional teaching dilemma where knowledge, capability, and competency are separated. Establishing a mapping relationship matrix of "teaching module-teaching method-value element" achieves full-chain integration from the knowledge input end to the capability and value output ends.

3 Results and Discussion

3.1 Teaching Objective Reconstruction

According to the proposed three-dimensional integrated teaching objective system, we systematically reconstructed the traditional teaching objectives of seven teaching modules from "Introduction" to "Search" in the Data Structures course. As shown in Table 2, traditional teaching objectives primarily focus on mastering knowledge and skills. In contrast, the reconstructed objective system, while maintaining knowledge transfer (concept understanding, algorithm mastery), strengthens the capability cultivation dimension (such as computational thinking cultivation, problem-solving ability, system

Table 2. Comparative analysis of data structures course teaching objectives integrating value-leading elements.

Teaching Module	Traditional Teaching Objectives	Reconstructed Teaching Objectives
Introduction	Master the basic concepts of data, data structures, and algorithms; understand the analytical methods for algorithm time and space complexity.	1. Knowledge Objectives: Be able to articulate the definitions of logical structures, storage structures, and operations of data structures. 2. Capability Objectives: Be able to apply complexity theory to evaluate the performance advantages and disadvantages of different algorithms in agricultural data analysis scenarios. 3. Value Objectives: Cultivate students to become rational innovators who are good at making trade-offs in agricultural intelligent technology selection.
Linear List	Master the sequential and linked storage structures of linear lists; be able to implement their basic operations (insertion, deletion, search).	1. Knowledge Objectives: Master the structural characteristics, implementation methods, and advantages/disadvantages of sequential lists and linked lists. 2. Capability Objectives: Be able to analyze and select appropriate linear list implementation schemes according to specific requirements of agricultural data management. 3. Value Objectives: Cultivate students' systematic thinking and decision-making capabilities in weighing pros and cons in agricultural systems engineering design.
Stack and Queue	Master the characteristics, storage structures, and basic operations of stacks and queues.	1. Knowledge Objectives: Understand the logical characteristics and physical implementation of stacks (LIFO) and queues (FIFO). 2. Capability Objectives: Be able to apply stacks and queues to solve typical problems such as instruction buffering and job queuing in agricultural task scheduling and equipment coordination. 3. Value Objectives: Cultivate students' work style of adhering to established protocols and conducting work rigorously in agricultural intelligent system design.
Tree and Binary Tree	Master the definitions, properties, storage structures, and traversal algorithms of trees and binary trees.	1. Knowledge Objectives: Master the basic terminology of tree structures, properties of binary trees, and their traversal algorithms. 2. Capability Objectives: Be able to apply tree structures to efficiently organize and manage agricultural data with hierarchical relationships, such as crop classification and organizational management. 3. Value Objectives: Cultivate students' information ethics and professional responsibility in protecting privacy and maintaining data security and integrity in agricultural information resource processing.
Graph	Master various storage structures of graphs; understand and implement depth-first and breadth-first traversal algorithms.	1. Knowledge Objectives: Master the basic concepts of graphs and storage structures such as adjacency matrix and adjacency list. 2. Capability Objectives: Be able to apply depth-first, breadth-first, and other traversal algorithms to solve complex engineering problems such as agricultural logistics path planning and IoT connectivity determination. 3. Value Objectives: Cultivate students' global perspective and teamwork awareness when solving large-scale agricultural system problems.
Sorting	Master the principles and implementation of different sorting algorithms and analyze their performance.	1. Knowledge Objectives: Understand the concepts and algorithm implementations of insertion, selection, exchange, and other sorting algorithms. 2. Capability Objectives: Be able to select and implement appropriate sorting algorithms based on the characteristics of agricultural datasets and application scenarios. 3. Value Objectives: Cultivate students' awareness of conserving computational and storage resources, as well as professional spirit of relentless pursuit and continuous optimization of efficiency in agricultural data processing practice.
Search	Master the principles and implementation of sequential search, binary search, and other algorithms.	1. Knowledge Objectives: Understand the working principles of different search algorithms and their requirements for data organization methods. 2. Capability Objectives: Be able to design and organize data to achieve efficient search in agricultural big data environments. 3. Value Objectives: Cultivate students' professional character of pursuing technical excellence and striving for excellence in agricultural algorithm optimization.

design capability), and innovatively integrates value elements (such as innovative spirit, engineering ethics, social responsibility, teamwork), achieving organic unity of "knowledge transfer-capability cultivation-value shaping." This reconstruction not only meets the requirements of international

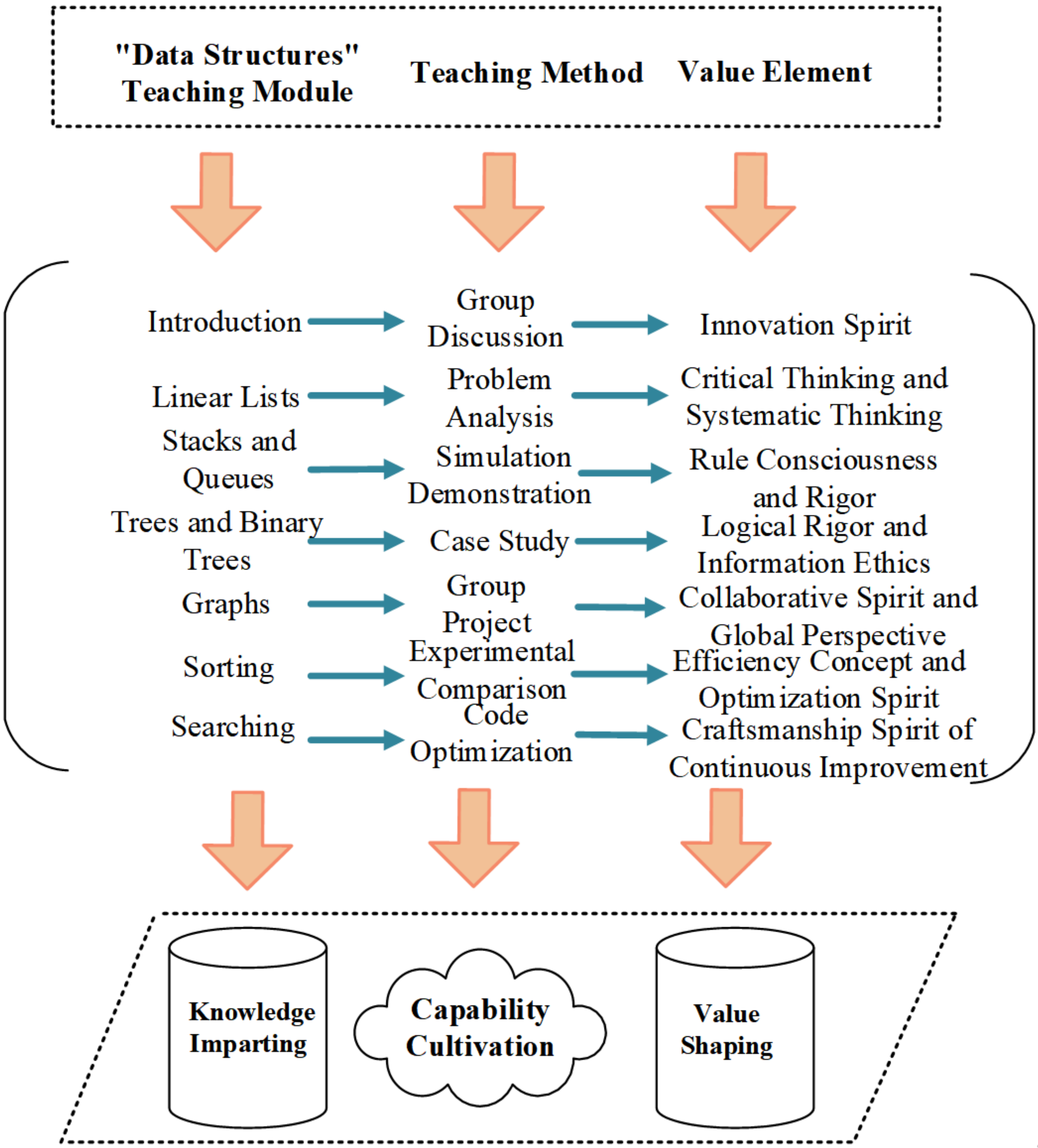

Figure 2. Teaching strategy framework.

engineering education accreditation standards but also provides a clear objective orientation for cultivating compound innovative talents adapted to new era demands [23, 24].

3.2 Teaching Content and Teaching Strategy Implementation Plan

To ensure that each module of the Data Structures course reform plan maintains close connections among teaching activities, knowledge transfer, capability cultivation, and value shaping objectives, forming a clear, coherent, and easily executable teaching closed loop oriented toward smart agriculture talent cultivation, the specific implementation plan is as follows:

1. **Introduction Module**
   When teaching algorithm performance evaluation,

Table 3. Comparison of two teaching models.

Round	Academic Year	Group	Number of Students	Mean Score	Standard Deviation
First	2023	Control Group	92	80.477	10.95304
		Experimental Group	89	85.337	8.22852
Second	2024	Control Group	81	78.943	11.50901
		Experimental Group	89	82.449	8.83949

this module organizes a structured group discussion. Teachers pre-design multiple differentiated application scenario cards derived from smart agriculture (such as crop growth monitoring data stream processing, agricultural machinery scheduling path calculation, etc.). After drawing lots in groups, students must evaluate the performance advantages and disadvantages of different structures, such as arrays and linked lists, based on scenarios and justify their final choices. Through discussing "why there is no universal data structure," students are guided to understand that "trade-off" is the core concept of agricultural intelligent system design. By introducing the pioneering work of pioneers in related fields, students are inspired to become rational innovators who are good at analysis and understand choices in agricultural technology selection.

2. **Linear List Module**
When explaining insertion and deletion algorithms for sequential lists, the problem "What are the performance bottlenecks of batch insertion at the head of a sequential list composed of large-scale agricultural sensor data?" is addressed. Through animation demonstrating the large-scale data movement triggered by each operation, students are guided to deeply analyze the profound impact of local operations on global performance. By comparing the advantages and disadvantages of sequential and linked storage of linear lists in agricultural data management, students understand the dialectical relationship between local and global agricultural information systems, thereby cultivating their critical thinking and systematic thinking capabilities.

3. **Stack and Queue Module**
This module employs simulation demonstration methods to strengthen students' understanding of stack and queue operation rules. Based on explaining the last-in-first-out rule of stacks and the first-in-first-out rule of queues, using examples such as "agricultural robot path backtracking" or "task queuing on agricultural product processing lines," students role-play and use props to simulate stack "backtracking" or queue "queuing" processes, personally experiencing that rule compliance is the prerequisite for algorithm success. Teachers analogize this to strict command sequences in coordinated operations of agricultural intelligent equipment, emphasizing that rules and contracts are the foundation of order and stability in complex agricultural production systems, thereby internalizing a rigorous work style as students' professional habits.

4. **Tree and Binary Tree Module**
The course introduces "agricultural enterprise organizational structure or field-level management" as a real case. Students are guided to analyze the entire tree structure starting from the "root node," understanding the importance of its hierarchical relationships. Students design data access or resource allocation schemes through case studies based on tree traversal. In this process, it is explicitly pointed out that technology developers have ethical responsibilities to protect data privacy and maintain information integrity when managing agricultural data, thereby organically integrating technical training in logical rigor with professional competency cultivation in information ethics.

5. **Graph Module**
Teaching in this module is supported by a group project on "agricultural regional logistics distribution network optimization" or "farmland IoT node connectivity analysis." Student groups must collaborate to complete graph construction, traversal, or the minimum spanning tree algorithm application. Students must communicate and collaborate like interconnected vertices in a graph during the project process to jointly design solutions. Through project practice and presentations, students sincerely

appreciate the role of individuals in complex agricultural production and marketing systems and the tremendous value of teamwork in solving global problems.

6. **Sorting Module**
   This module requires students to compare the performance of different sorting algorithms when processing agricultural meteorological or yield data through experiments. Students must write code and test running time on datasets of different scales and states, recording and analyzing performance differences. Teachers guide students to deeply perceive from experimental results the significance of "time and space" as precious computational resources in real-time agricultural decision-making, thereby cultivating students' professional spirit of relentless pursuit and continuous optimization of efficiency in agricultural software engineering practice.

7. **Search Module**
   The teaching focus of this module is to guide students to practice "excellence pursuit" in the context of agricultural big data retrieval. Students are required not only to implement search functions but also to use performance profiling tools to analyze bottlenecks and repeatedly scrutinize and optimize code details, such as boundary conditions and computational processes, to meet agricultural applications' stringent response speed requirements. Through this practice process of pursuing excellence, students experience the leap from "usable" to "high-quality," thereby internalizing the craftsmanship spirit of excellence pursuit as their core professional character.

3.3 Teaching Reform Experiment Discussion

This study is based on the Software Engineering program at Jiangxi Agricultural University, which is committed to cultivating compound talents with solid engineering capabilities and interdisciplinary competencies in emerging fields such as smart agriculture. Based on this background, using the Data Structures course as a vehicle, we conducted a teaching reform experiment lasting two teaching cycles. The first round of experiments established a control group (92 students) and an experimental group (89 students); the second round of experiments similarly established a control group (81 students) and an experimental group (89 students), systematically testing the effectiveness of the teaching model integrating value leadership in actual teaching.

As shown in Table 3, experimental group students receiving the new teaching model demonstrated comprehensive advantages in academic performance. In the first round of experiments, the experimental group's average score reached 85.337 points, significantly higher than the control group's 80.477 points; in the second round of experiments, the experimental group's average score was 82.449 points, still markedly better than the control group's 78.943 points. Meanwhile, the standard deviation of the experimental group students' scores significantly decreased. The aforementioned differences have statistical significance through an independent samples t-test verification ($p < 0.05$). Experimental results verified that teaching reform integrating value leadership can achieve coordinated development of knowledge transfer, capability cultivation, and value shaping while maintaining original teaching scale conditions.

3.4 Research Value and Limitations

Based on the abstract competency requirements in international engineering education standards, this study systematically integrates value elements from the smart agriculture domain into the teaching model of data structures programming practice. This model transforms value objectives such as "systematic engineering decision-making" and "data security and privacy protection" into a series of specific teaching activities embedded in agricultural data analysis and intelligent decision-making tasks, providing a clear implementation pathway for achieving value guidance in professional courses. Practice has demonstrated that systematic reconstruction centered on the "teaching objectives-content-strategies" framework is a practical approach to promoting the paradigm shift in engineering education from "technical capability-oriented" to "comprehensive competency-oriented."

The limitations of this study are primarily reflected in the assessment of character development effectiveness. Although improvements in academic performance and the narrowing of standard deviations provide objective evidence of teaching effectiveness, the assessment of the internalization degree of value dimensions, such as "information ethics" and "craftsmanship spirit," still mainly relies on qualitative methods, including classroom observation. The key to future research lies in exploring the integration of value measurement theories from psychology and pedagogy [25] with the professional context of smart agriculture, to construct a comprehensive evaluation system that possesses both disciplinary characteristics and scientific rigor, thereby achieving the deepening of values-integrated teaching from "implementable" to "accurately assessable."

4 Conclusion

This study systematically constructed a three-dimensional integrated teaching objective system of "knowledge-capability-values" oriented toward smart agriculture by applying Checkland's Soft Systems Methodology, and accordingly completed a comprehensive reconstruction from course content to teaching strategies. Two rounds of teaching practice have demonstrated that this model not only significantly improves students' academic performance but also effectively cultivates the systems thinking, ethical awareness, and professional responsibility required for the smart agriculture domain. These results confirm that systematic teaching reconstruction based on SSM can effectively achieve the organic integration of professional education and values education, providing a practice-tested and replicable pathway for teaching reform in relevant agriculture-related universities. Subsequent research will focus on exploring quantitative assessment methods for character development to enhance further the scientific rigor and application breadth of this teaching model.

Data Availability Statement

Data will be made available on request.

Funding

This work was supported by the Key Project of Jiangxi Provincial Higher Education Teaching Reform Research under Grant JXJG-23-3-4.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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