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Teaching Reform of Microprocessor Course under Smart Forestry Background: A Case Study of Micro-Lesson Design for RS-485 Interface

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Abstract. Microprocessor systems are fundamental to equipment intelligence; the rapid advancement of smart forestry has created new demands for reforming the Microprocessor Course in forestry universities. Traditional teaching methods often emphasized theory over practice and general applications over industry-specific characteristics, limiting students' ability to solve real-world forestry engineering problems. This study presented a teaching reform initiative at Nanjing Forestry University, using the RS-485 interface as an example to design a scenario-based micro-lesson rooted in smart forestry. The reform integrated on-site teaching at forestry bases, instrument measurement demonstrations, and ideological and political elements, aiming to cultivate electromechanical talents with agricultural and forestry expertise. A quasi-experimental design was employed with two cohorts: the questionnaire analysis included valid responses from the control class (Grade 2023 of Intelligent Manufacturing, *n*=57) received the existing PPT-based instructional approach, while the experimental class (Grade 2024 of Intelligent Manufacturing, *n*=54) adopted the proposed micro-lesson model. Questionnaire responses indicated higher proportions of favorable ratings in the experimental cohort across knowledge comprehension, learning interest, engineering cognition, and professional identity; The findings suggest that the scenario-based micro-lesson may help connect theoretical learning with industrial practice and support students' perceived engagement and professional relevance. This reform provides a practical reference for improving microprocessor education and supporting talent development in smart forestry.

Keywords: Microprocessor course; smart forestry; micro-lesson design; on-site teaching; engineering education

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1. Introduction

The Microprocessor Course serves as a core specialized subject designed to enhance students’ competence in computer applications. It helps learners develop programming and design skills for microcontroller systems that align with industrial development needs (Tupac-Yupanqui et al., 2022). In the context of intelligent equipment transformation, microcomputer systems function as central control units, supporting intelligent capabilities such as perception, decision-making, and execution (Ryalat et al., 2024). They play a crucial role in industrial control, the Internet of Things (IoT), and intelligent monitoring fields (Sudharsan et al., 2022).

Smart forestry, as the core development direction of modern forestry, relies heavily on embedded technology for intelligent upgrades (Arion et al., 2025). Typical applications of microcontroller unit (MCU) technology in smart forestry include forest environment monitoring nodes (Ehrlich-Sommer et al., 2024), remote pest and disease monitoring devices (Bibi et al., 2026), tree growth tracking terminals (Venanzi et al., 2023), and forest fire early warning sensors (Lou et al., 2026). However, the Microprocessor Course was primarily concerned with general scenarios such as industrial control, factory monitoring, and smart home appliances, which had little connection to the professional backgrounds and likely career paths of forestry university students (Hafiz et al., 2025). This teaching style, which was detached from the actual forestry business, hindered teaching efficacy while also deviating from forestry institutions' talent training goals. As a result, it may not fully support students in developing the context-specific skills required for smart-forestry applications (Daniela, 2021). This industry-curriculum mismatch creates an urgent practical demand for targeted teaching reform. Forestry electromechanical graduates are expected to master RS-485 communication to operate field monitoring terminals, yet current university training fails to deliver scenario-specific technical training, which forms the core practical motivation for this research.

Specifically, the Microprocessor Course often exhibited notable shortcomings in both theoretical and experimental instruction. In theoretical teaching, the course content often emphasized a limited range of commonly used hardware platforms. Published course designs have used STM32 and Arduino as practical platforms for programming and IoT laboratories (Jacko et al., 2022). In the course context considered here, theory-oriented materials provided limited connection to engineering practice, whereas development-focused materials emphasized that library-function calls for more than the underlying logic. These characteristics could restrict opportunities for students to connect principles with practical design decisions. Furthermore, theoretical assessments were disconnected from practical applications and relied on one-dimensional examinations (Pasricha, 2022). For example, serial communication, a core technology enabling microcontrollers to interact with external devices, incorporated knowledge of logic circuits, signal encoding, and timing control derived from digital electronics. However, assessments that focus mainly on software coding in isolation, make it difficult for students to develop a holistic understanding of coding implementation, hardware connections, and operational mechanisms (Wardiyani et al., 2021). Consequently, students may develop a fragmented knowledge structure and have limited opportunities to practice integrated engineering problem-solving.

In terms of experimental teaching, there was also a problem of insufficient practicality. Owing to restricted class time, experimental material was frequently reduced into simple verification modules such as GPIO, interrupts, and serial communication (Farrar, 2021). This made it difficult to guide students through a thorough skill progression that ranged from understanding principles to practical application and engineering. For example, the serial communication experiment involved core data exchange functions critical to industrial control (Behseresht et al., 2024), IoT (Friedrich & Reggiani, 2024), and smart hardware (Gong et al., 2020). It encompassed real engineering challenges such as data protocol design (Jeong et al., 2026), error-checking mechanisms (Ouederni, 2021), and multi-device communication conflict resolution (Sládek et al., 2025). However, current experiments mostly focused on simple functional verification, such as character loopback, only achieving fixed data transmission and reception (Li et al., 2021). This approach provided limited connection to practical application scenarios and offered limited support for understanding the engineering significance of serial communication (Maxworth, 2023). Overall, existing experiments were primarily verification-oriented; students mainly followed instructions to complete tasks, making it difficult to relate to real-world engineering projects such as intelligent control and embedded development (Szabó et al., 2025). Consequently, these experiments may not fully address the context-specific competencies expected of interdisciplinary electromechanical graduates in smart forestry. Collectively, these theoretical and experimental limitations fragment students' engineering thinking and disconnect classroom learning from real forestry engineering projects, demonstrating the inherent defects of the traditional microprocessor teaching system that this study intends to address.

Existing literature has explored micro-lesson optimization for microprocessor courses, yet most reform cases focus on general manufacturing and electronic engineering majors (Jacko et al., 2022; Taali et al., 2024). Research on RS-485 in smart forestry mainly focuses on hardware circuit and communication algorithm design (Friedrich & Reggiani, 2024; Sládek et al., 2025), with few studies integrating forest field practice, visualized instrument demonstration, and vocational guidance into a unified RS-485 micro-lesson model. This study fills three distinct research gaps:

Across the educational literature, application-oriented microcontroller teaching has been implemented through remote laboratories, structured experiments with open-ended projects, and blended instruction. A remote STM32 IoT laboratory reported improved task completion (Jacko et al., 2022); a laboratory curriculum combining structured experiments and open-ended projects reported stronger complex engineering problem-solving outcomes (Hafiz et al., 2025); and a quasi-experimental microprocessor study reported improved learning outcomes under blended instruction (Taali et al., 2024). These studies support active, laboratory-based learning; however, they were conducted in general electrical or electronic engineering settings rather than smart forestry.

The technical literature establishes the relevance of the application context. Smart- and precision-forestry reviews identify sensor networks, IoT, automation, and associated workforce skills as important to digital forest management (Arion et al., 2025; Vatandaslar et al., 2025), while RS-485 research demonstrates the integration of low-cost sensors in distributed monitoring systems (Sládek et al., 2025). This literature supports the technical context; however, it does not evaluate an undergraduate design combining forestry field practice, waveform visualization, and career guidance.

In terms of the knowledge gap, existing microprocessor teaching ignores smart forestry scenarios, and RS-485 forest hardware research lacks replicable undergraduate teaching schemes (Jacko et al., 2022; Taali et al., 2024; Friedrich & Reggiani, 2024; Sládek et al., 2025). As far as the empirical gap is concerned, no prior work uses quasi-experimental cross-cohort questionnaires to quantify the teaching effect of field-based visualized RS-485 micro-lessons for forestry majors. Finally, there is a conceptual gap: scenario-based teaching theory is rarely applied to interdisciplinary agriculture-forestry embedded courses, and this study extends its application boundary.

No prior empirical research has quantitatively evaluated the teaching effect of forestry-situational embedded micro-lessons by means of questionnaire comparison, which represents a clear academic research gap that this study fills. Currently, smart forestry has rapidly advanced in areas such as integrated space-air-ground monitoring (Fu et al., 2026), precise carbon sink measurement (Ren et al., 2026), and intelligent disaster early warning (Torresan et al., 2021). Forestry management fully transitioned from the traditional experience-driven model to a modern data-driven, intelligent collaboration approach (Damaševičius et al., 2024; Dong et al., 2025). Against this backdrop, cultivating outstanding agricultural and forestry talent became a critical objective for higher education in these fields (Shi et al., 2025).

Developing an interdisciplinary Microprocessor Course that integrated forestry scenarios with IoT technology became increasingly important in undergraduate education (Vatandaslar et al., 2025). To address the aforementioned teaching challenges, a reform of the Microprocessor Course was implemented. RS-485 is an important communication route between microcomputer systems and external devices, such as forest environment monitoring nodes and fire early warning sensors (Castro et al., 2017). Mastery of its principles and engineering applications helped students comprehend the operational mechanics of microcomputer systems while also improving their practical engineering skills, allowing them to better meet the talent demands of smart forestry. Using the RS-485 interface as the foundation, a micro-lesson teaching model was created for smart forestry scenarios. This study summarizes the practical teaching outcomes of the reform and provides a valuable reference for optimizing similar professional courses.

Combined with real-world industry-teaching contradictions and the above knowledge, empirical and conceptual gaps, this research bridges the gap between general embedded teaching and forestry engineering practice, thereby filling the identified research voids and clarifying its practical necessity and academic relevance. Accordingly, this study aimed to compare student-reported evaluations of a scenario-based RS-485 micro-lesson with those of the existing PPT-based approach across four dimensions: teaching content, teaching methods, learning outcomes, and career guidance. Two research questions guided the analysis: (a) How did the two cohorts differ in their evaluations of teaching content and teaching methods? and (b) How did the two cohorts differ in their self-reported learning outcomes and career guidance?

The study makes three bounded contributions. Pedagogically, it specifies a field-practice, signal-visualization, and value-guidance sequence for an RS-485 micro-lesson. Contextually, it links core microprocessor content with authentic smart-forestry sensing tasks while retaining the common syllabus. Empirically, it provides a cautious four-dimensional cross-cohort comparison of student-reported responses and identifies priorities for subsequent controlled studies.

2. Materials and Methods

2.1 Optimization Design of Teaching Content

2.1.1 Participants, design, sampling, and baseline learning profile

This study used a non-equivalent, post-test-only cross-cohort quasi-experimental design. The accessible population comprised the only intact Intelligent Manufacturing class in each of two successive entry cohorts, with 61 students in each cohort and 122 students in total. Both intact classes were included through convenience sampling. The questionnaire analysis used 57 valid responses from the Grade 2023 cohort and 54 valid responses from the Grade 2024 cohort. At the time of data collection, both cohorts were at the same curricular stage: the end of the second semester, immediately after completing the Microprocessor Course. The Grade 2023 cohort completed the course and questionnaire in June 2024, whereas the Grade 2024 cohort completed the same course and questionnaire in June 2025. The comparison therefore did not involve students at different stages of academic progression.

In terms of comprehensive literacy, all students demonstrated strong information literacy and adapted well to Internet-based learning methods. Most learners completed basic experimental box operation tasks under teachers' guidance; however, they lacked practical experience with on-site industrial application cases. Their ability to debug programs using professional testing tools remained insufficient, and there was a need to improve their overall skills in applying electronic circuits comprehensively. As far as learning characteristics are concerned, students preferred intuitive, practice-oriented learning methods such as on-site case analysis and group discussions and tended to have low concentration during purely theoretical explanations. The course was therefore designed to strengthen professional responsibility and awareness of current developments in modern agriculture and forestry.

Here, learning characteristics refers to students' reported preference for practical and visualized learning activities and their lower levels of concentration during abstract theoretical explanations. This observed learning profile informed the choice to combine field demonstration and visual explanation with, rather than replace, the core theoretical content. Convenience sampling refers to the inclusion of the only intact Intelligent Manufacturing class available in each entry cohort rather than the random assignment of individual students. Because the program had only one intact class per cohort, a contemporaneous intact-class control and experimental comparison within the same cohort was unavailable. The use of two successive intact cohorts made it possible to compare the existing instructional approach with the revised micro-lesson at the same point in the curriculum without dividing the only scheduled class.

2.1.2 Teaching objectives

Knowledge objectives: Learners gained an understanding of the fundamental concepts and differential transmission characteristics of RS-485 interface. They became familiar with conventional hardware connection methods and operating principles and explored common applications of RS-485 technology.

Ability objectives: Learners were able to analyze the data frame structure and actual signal waveforms of RS-485, establishing a solid foundation for using common testing instruments to complete terminal debugging tasks. This relevant learning experience supported the practical skill development of students pursuing careers in intelligent manufacturing within the agriculture and forestry sectors.

Value objectives: Classroom teaching activities enhanced learners' self-confidence in professional development, promoted a rigorous work ethic and a dedicated craftsman spirit, and deepened career recognition among electromechanical majors regarding grassroots positions in agriculture and forestry.

The overall instructional design framework is illustrated in Figure 1. The intervention used a field-practice, visualized-demonstration, and value-guidance framework, as shown in Figure 1. The framework was adapted for this course from the situational blended micro-lesson model (Taali et al., 2024). The micro-lesson teaching materials were reviewed and optimized by three forestry electromechanical professional experts before classroom implementation to ensure alignment with syllabus requirements. The complete micro-lesson intervention model was reviewed, revised, and comprehensively evaluated by three forest-mechatronics and embedded-teaching experts before classroom implementation.

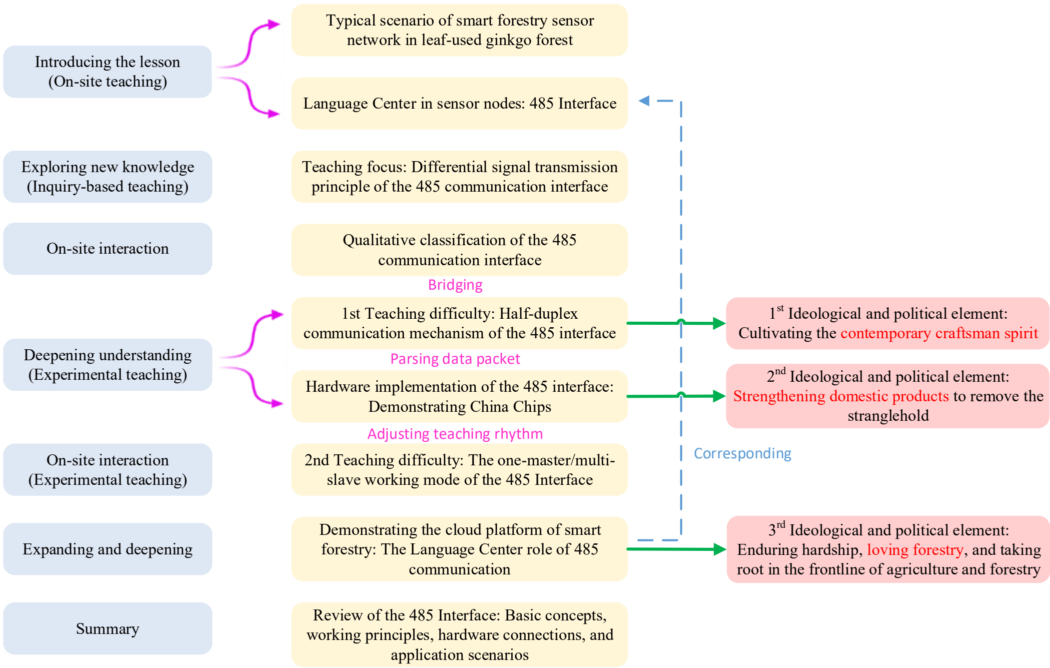

Figure 1: Framework of micro-lesson design

2.2 Optimization of Teaching Methods

2.2.1 On-site teaching method

All instructional design content was centered on the demands of the smart forestry industry. On-site teaching activities were conducted at a ginkgo forest planting base in Pizhou City, Jiangsu, China(Figure 2). Practical requirements for soil moisture monitoring were identified on site, and real-world applications of soil water and fertilizer sensing networks in smart forestry construction were demonstrated. Classroom instruction focused on the RS-485 interface protocols between microcontrollers and soil monitoring sensors used in field terminal equipment, naturally leading into the core teaching material of this lesson. This on-site teaching approach overcame the limitations of traditional classroom settings, enriched students' experiential understanding, and stimulated intrinsic learning motivation. The ginkgo forest base in Pizhou City is selected as the research site for targeted rationales: It is a provincial-level smart forestry demonstration base fully equipped with RS-485-based soil humidity sensing networks and complete on-site MCU monitoring terminals. The real field equipment can directly match the core RS-485 teaching cases of this micro-lesson, providing authentic industry scenarios unavailable in campus laboratories.

The site context included a provincial smart-forestry demonstration base, an RS-485 soil-sensing network, field MCU monitoring terminals, and testable signal equipment. These content elements were selected by matching the core MCU-RS-485 syllabus points with functions available in the field hardware.

Figure 2: On-site teaching practice of RS-485 interface technology in forestry base.

2.2.2 Demonstration teaching method

Visualized waveform observation helped deepen students' understanding of the internal operating mechanisms of RS-485 interface. Instead of directly displaying standard waveform diagrams in textbooks, oscilloscopes were used to capture real communication signals between RS-485 interface modules and sensors on-site, verifying the actual data frame formats against the results displayed on the upper computer (laptop) (Figure 3). Combined with dynamic demonstrations of experimental results, the timing rules of differential signal transmission and the voltage level changes of RS-485 interface for students were clarified (Figure 4). The design follows situational-learning and visual-cognitive principles for engineering education, namely field context establishes relevance, while waveform visualization links abstract timing rules to observable signals.

Static screenshots of experimental data and test waveforms were transformed into dynamic demonstrations, creating a vivid and intuitive learning experience for students. Field demonstration activities also helped students recognize that practical operational skills were just as important as mastering theoretical knowledge. Students could develop good habits of using professional instruments to conduct field observations and troubleshoot problems. The teaching content encompassed all core knowledge points specified in the syllabus and extended practical application beyond the textbook scope. Inquiry-based field experiments bridged the gap between learners and abstract professional concepts, effectively addressing key challenges and reinforcing learning outcomes.

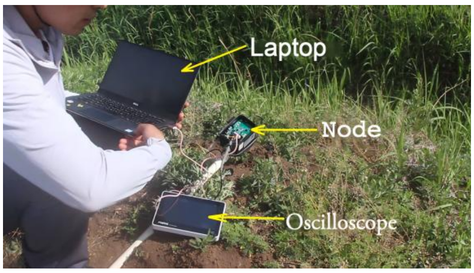

Figure 3: Field experimental operation of RS-485 interface

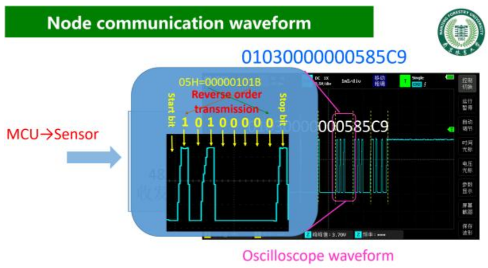

Figure 4: Actual measured waveforms and standard data frames of RS-485 interface

2.3 Integration of Ideological and Political Elements

This micro-lesson integrated three major types of ideological and political education content. First, field instrument testing practice guided students to develop independent operational awareness and cultivate a rigorous craftsman spirit. Second, an in-depth explanation of the hardware design schemes for RS-485 interface highlighted the achievements of domestically developed chips, enhancing students' sense of mission to overcome core technical barriers. Third, extended learning sessions showcased the operation modes of a cloud management platform designed for a ginkgo forest planting base. Through this, students gained a comprehensive understanding of the critical role of RS-485 interface technology in smart forestry systems, further strengthening their professional identity and solidifying their commitment to serving grassroots agriculture and forestry development.

Students' recognition of grassroots forestry career identity and acquisition of craftsman spirit were measured through the career-guidance dimension items of the post-class questionnaire for quantitative verification.

2.4 Methods for Evaluating Teaching Effectiveness

Building on the design concepts outlined above, this research completed the targeted production of a micro-lesson focused on the RS-485 interface. The teaching content integrated explanations of technical principles, practical applications in forestry scenarios, and guidance on professional value.

An experimental comparison method was employed to evaluate the practical application effects of the new teaching model. Students majoring in Intelligent Manufacturing from two different grades were selected as research subjects to conduct a cross-year comparative teaching study. This study adopts a non-equivalent pre-test-post-test quasi-experimental design rather than a randomized controlled trial. Sufficient justifications for this design choice are elaborated as follows: First, random grouping of students within the same grade is impossible under fixed university teaching timetables; the school arranges intact class cohorts for all professional courses, which eliminates the feasibility of random assignment. Second, Grade 2023 and Grade 2024 undergraduates share identical pre-major curricula, including circuit fundamentals and C programming, with no obvious gap in prior embedded knowledge. Neither cohort has participated in forest monitoring engineering internships before this course, which guarantees baseline comparability between the two groups. Third, strict control variables are set to reduce interference factors: the same instructor, unified syllabus, consistent class hours, identical assessment standards, and uniform hardware experimental equipment are applied to both cohorts. The only independent variable is the differentiated micro-lesson teaching mode. Fourth, quasi-experimental cross-cohort comparison is the most operable empirical scheme under real classroom teaching conditions, which can objectively reflect the actual teaching effect of the reform model without disrupting normal semester teaching arrangements.

The control class consisted of 61 students in Grade 2023 who received typical PPT lecture-based instruction without micro-lesson additional learning components. Their necessary teaching assignments were completed by June 2024. The experimental class consisted of 61 students from Grade 2024. Innovative teaching methods, such as scenario-based micro-lesson explanations and instrument demonstrations, were incorporated into classroom training, with a June 2025 teaching timetable. Apart from differences in teaching time and student cohort, both classes maintained consistency in curriculum syllabus, teaching content, class hour allocation, assessment criteria, and teacher assignment, which reduced some instructional differences, although cohort and temporal effects remained.

After viewing a self-designed micro-lesson video on the RS-485 interface in the Microprocessor Course, an online questionnaire survey (Sojump, Ranxing Information Technology Co., Ltd., Hunan, China) was conducted to collect students' learning feedback. The analysis used 57 valid responses from the control cohort and 54 valid responses from the experimental cohort and compared favorable-response proportions. The result tables retain the reported categorical significance annotations (* for $p < 0.05$ and ** for $0.05 \leq p < 0.10$). Control-group material consisted of the existing PPT-based lecture materials and textbook schematic explanations; experimental-group material added the scenario-based RS-485 micro-lesson, forestry field footage, instrument demonstrations, and engineering cases. The core syllabus content was retained for both cohorts.

The intervention was defined as the delivery of the scenario-based RS-485 micro-lesson, including forestry field observation and instrument demonstration, to the Grade 2024 experimental cohort; the Grade 2023 cohort continued with the existing PPT-based approach.

The questionnaire contained 17 items. The core evaluation section comprised 13 single-choice items covering four dimensions: teaching content (Items 1–3), teaching methods (Items 4–7), learning outcomes and interest (Items 8–10), and career guidance and value cultivation (Items 11–13). Item 14 assessed overall satisfaction, item 15 allowed students to select multiple teaching components that they considered valuable, while items 16–17 collected open-ended suggestions concerning improvement and future micro-lesson design. The single-choice items used construct-specific ordered five-category response options, with category labels reflecting clarity, helpfulness, improvement, mastery, satisfaction, or other item-specific evaluations. Because the response anchors differed across constructs, the items were not treated as one uniform agree–disagree scale. For the single-choice items reported in Tables 1–4, the two most favorable categories were combined to calculate favorable-response proportions; no composite questionnaire score was calculated.

Questionnaire development was guided by the course objectives, the micro-lesson design framework, and the four evaluation dimensions. Before formal administration, three experts in forest electromechanics and embedded-systems teaching reviewed all 17 items for clarity, relevance, content coverage, and alignment with the course objectives; item wording was revised in response to their feedback. The questionnaire yielded an overall Cronbach's alpha of 0.872, indicating good internal consistency.

2.5 Ethical Considerations

All student participants participated in the questionnaire survey voluntarily without compulsory requirements. All questionnaire data were anonymized, without recording names, student numbers, or other personally identifiable information. All collected data were used only for this teaching-reform academic research and not for commercial or administrative evaluation purposes. Verbal informed consent was obtained from all students before they completed the questionnaire.

3. Results and Discussion

3.1 Statistical Analysis of Survey Data

The unified interpretation cut-off point for inferential statistics was defined as $p < 0.05$ for statistically significant inter-group differences, while $0.05 \le p < 0.10$ was defined as a marginally significant trend without conclusive evidence of an inter-group difference. After sorting the investigation results, 57 valid questionnaires were recovered from the control class, accounting for 93.44% of the total participants. The experimental class obtained 54 valid questionnaires, with an effective recovery rate of 88.52%. A detailed comparative analysis of the survey data across four evaluation dimensions was presented as follows:

3.1.1 Evaluation of teaching content

Table 1 shows consistently higher favorable-response proportions in the experimental cohort. Favorable responses for the clarity of core knowledge explanations were 96.30% in the experimental cohort and 71.93% in the control cohort, representing a difference of 24.37 percentage points. The corresponding proportions were 92.59% versus 59.65% for resolving difficult professional knowledge, a difference of 32.94 percentage points, while 92.60% versus 68.42% for connecting the RS-485 content with STM32 knowledge, a difference of 24.18 percentage points. According to the significance annotations in Table 1, the first two comparisons met the $p < 0.05$ criterion, whereas the STM32-connection item showed a marginal difference at $0.05 \le p < 0.10$. The largest difference concerned the resolution of difficult professional knowledge, suggesting that the visual and hierarchical organization of the micro-lesson was particularly helpful in making abstract communication principles easier for students to understand.

Table 1: Students' evaluation of teaching content

Evaluation Item	Option	Control Class/%	Experimental Class/%
Clarity of core knowledge explanation	Very clear/ Relatively clear	71.93	96.30*
Solution of obscure professional knowledge	Fully solved/ Basically solved	59.65	92.59*
Knowledge connection with STM32 content	Extremely close/Relatively close	68.42	92.60**

*Note: Values are favorable-response proportions (%) calculated from valid questionnaire responses. * indicates $p < 0.05$; ** indicates $0.05 \le p < 0.10$*

3.1.2 Evaluation of teaching methods

Table 2 shows that the largest difference between the cohorts concerned the contribution of experimental demonstrations to engineering cognition: favorable responses reached 90.74% in the experimental cohort, compared with 45.61% in the control cohort, a difference of 45.13 percentage points. Animation demonstrations were also evaluated more favorably by the experimental cohort for reducing the difficulty of abstract concepts (79.63% vs. 40.35%; difference: 39.28 percentage points). For group discussion, the corresponding proportions were 75.93% and 54.39%, a difference of 21.54 percentage points. The experimental demonstration and animation items met the $p < 0.05$ criterion, while the group discussion item showed a marginal difference at $0.05 \leq p < 0.10$. This pattern indicates that direct equipment demonstrations and dynamic visualization were the most strongly recognized components of the revised teaching approach, while group discussion provided additional support for students' understanding.

Table 2: Students' evaluation of teaching methods

Evaluation Item	Option	Control Class/%	Experimental Class/%
Improvement of engineering cognition by experimental demonstration	Greatly improved/ Slightly improved	45.61	90.74*
Difficulty reduction effect of animation demonstration	Greatly reduced/ Slightly reduced	40.35	79.63*
Auxiliary effect of group discussion on learning	Strongly helpful/ Moderately helpful	54.39	75.93**

*Note: Values are favorable-response proportions (%) calculated from valid questionnaire responses. * indicates p < 0.05; ** indicates 0.05 ≤ p < 0.10*

3.1.3 Evaluation of learning outcomes

As shown in Table 3, favorable responses concerning improved learning interest were 88.89% in the experimental cohort and 54.39% in the control cohort, a difference of 34.50 percentage points. The experimental cohort also reported higher favorable responses for understanding the practical application value of RS-485 technology (87.04% vs. 50.88%; difference: 36.16 percentage points) and mastering basic problem-analysis methods (85.19% vs. 49.12%; difference: 36.07 percentage points). All three comparisons met the $p < 0.05$ criterion shown in Table 3. The similarly-sized differences across interest, practical relevance, and problem-analysis methods suggest that connecting RS-485 principles with authentic forestry applications supported both students' engagement and their perceived ability to transfer theoretical knowledge to engineering problems.

Table 3: Students' evaluation of learning outcomes

Evaluation Item	Option	Control Class/%	Experimental Class/%
Improvement of learning interest	Greatly promoted/ Slightly promoted	54.39	88.89*
Cognition of practical application value	Fully understood/ Basically understood	50.88	87.04*
Mastery of problem analysis methods	Fully mastered/ Basically mastered	49.12	85.19*

*Note: Values are favorable-response proportions (%) calculated from valid questionnaire responses. * indicates p < 0.05; ** indicates 0.05 ≤ p < 0.10*

3.1.4 Evaluation of career guidance

Table 4 shows that favorable responses concerning willingness to pursue grassroots employment were 74.07% in the experimental cohort and 42.11% in the control cohort, a difference of 31.96 percentage points. Larger differences were observed for guidance on cultivating a craftsman spirit (98.15% vs. 43.86%; difference: 54.29 percentage points) and understanding industry-development prospects (98.15% vs. 45.61%; difference: 52.54 percentage points). Overall course satisfaction was also higher in the experimental cohort (96.30% vs. 66.67%; difference: 29.63 percentage points). The craftsman-spirit, industry-prospect, and satisfaction comparisons met the $p < 0.05$ criterion, whereas willingness to pursue grassroots employment showed a marginal difference at $0.05 \leq p < 0.10$. These findings indicate that the career-guidance content was particularly effective in making professional values and smart-forestry development prospects more salient to students. The comparatively smaller difference in grassroots-employment willingness suggests that career intentions may require more sustained exposure than a single course component.

Table 4: Students' evaluation of career guidance

Evaluation Item	Option	Control Class/%	Experimental Class/%
Inspiration for grassroots employment willingness	Strongly inspired/ Slightly inspired	42.11	74.07**
Guidance effect on craftsman spirit cultivation	Strongly guided/ Slightly guided	43.86	98.15*
Cognition of industry development prospect	Fully clear/ Basically clear	45.61	98.15*
Overall course satisfaction	Very satisfied/ Relatively satisfied	66.67	96.30*

*Note: Values are favorable-response proportions (%) calculated from valid questionnaire responses. * indicates p < 0.05; ** indicates 0.05 ≤*

3.2 Previous Studies and Future Optimization Directions

Within the experimental cohort, overall course satisfaction was 96.30%. Students most frequently identified field investigations, dynamic animation displays, and instrument demonstrations as valuable teaching methods (Figure 5). These preferences support continued evaluation of these components; however, they do not by themselves establish a causal effect of the teaching model.

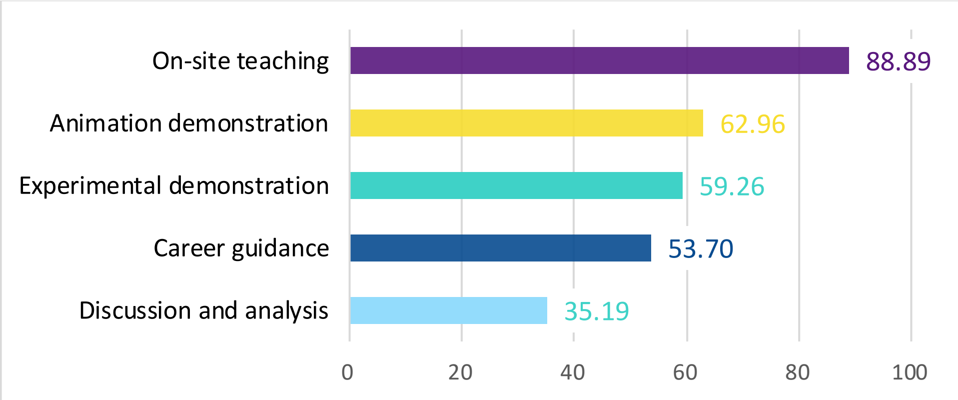

Figure 5: Proportional statistics of students' recognition of valuable teaching methods

Across the four evaluation dimensions, the largest between-cohort differences concerned guidance on cultivating a craftsman spirit (54.29 percentage points), understanding industry-development prospects (52.54 percentage points), improvement of engineering cognition through experimental demonstrations (45.13 percentage points), and reduction of conceptual difficulty through animation (39.28 percentage points). This pattern suggests that the micro-lesson received the strongest student recognition when it connected abstract RS-485 principles with visible technical processes, physical equipment, and authentic forestry applications. This interpretation is consistent with application-oriented microcontroller research showing that laboratory activities, structured engineering tasks, and contextualized instruction can strengthen students' engagement with complex technical content (Jacko et al., 2022; Hafiz et al., 2025).

The higher favorable responses for learning interest, practical application value, and problem-analysis methods also correspond with the findings of Taali et al. (2024) concerning blended microprocessor instruction. In addition, the strong responses concerning craftsman-spirit guidance and industry-development prospects support the relevance of connecting embedded-system education with the growing demand for sensor, automation, and digital skills in smart forestry (Arion et al., 2025; Vatandaslar et al., 2025). Taken together, these comparisons suggest that the principal value of the micro-lesson lies not only in presenting RS-485 knowledge visually, but also in helping students understand why this knowledge matters in realistic engineering and professional contexts.

Several limitations should be considered. The two cohorts came from different academic years, therefore cohort and temporal effects cannot be separated from differences in teaching approach, a trade-off which was fully explained when justifying the adoption of cross-year quasi-experimental design in subsection 2.4. The study was conducted at one university and relied on self-reported questionnaire responses, which limits generalizability and does not directly establish changes in objective knowledge or practical skill. In addition, the present tables report response proportions without sufficient information about the inferential tests, effect sizes, or measurement validity. The findings should therefore be interpreted as preliminary and context specific.

The newly reported Cronbach's alpha coefficient and expert content-validity review provide the available questionnaire measurement evidence; detailed item-level validation and effect-size reporting remain priorities for future research. Future research should add semi-structured interviews or focus-group discussions to collect qualitative evidence about students' experiences with the model and to complement the present questionnaire data.

Based on the questionnaire responses, course instructors should align on-site activities and instrument demonstrations with explicit learning objectives and comparable assessment tasks. Curriculum designers should connect RS-485 principles to authentic forestry-monitoring applications while retaining the core microprocessor syllabus. Future studies should use contemporaneous comparison groups, validated questionnaires, objective measures of knowledge and practical skill, and, where feasible, interviews or focus groups to examine students' experiences and the transferability of the approach.

4. Conclusion

In the context of rapid advances in smart forestry, the standard Microprocessor Course had several flaws, including an overemphasis on theory rather than actual application and a concentration on generic knowledge rather than industry-specific information. It was no longer able to fulfil the demand for multidisciplinary electromechanical specialists with strong technical skills, situational awareness, and practical capabilities in the smart forestry industry, necessitating curriculum change.

Serving as the central communication hub linking sensors and data systems in smart forestry, the RS-485 interface functioned as a crucial bridge connecting microprocessor knowledge with practical forestry applications. The reform focused on this micro-lesson successfully achieved the goals of technical instruction, scenario-based application, and value cultivation. It demonstrated the effectiveness of scenario-driven content design, visualized teaching methods, and career-oriented competency training. This reform helped students overcome technical learning barriers and appreciate the practical relevance of related forestry disciplines, providing a viable approach for cultivating specialized talent.

Continuous improvements in the Microprocessor Course could cultivate qualified electromechanical professionals who meet the needs of grassroots forestry development, drive the progress of smart forestry, and achieve a deep integration between higher education and industrial development.

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6. Conflict of interest

The authors declare no competing financial interests or personal relationships that could affect the work reported in this study.

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