An Exploration of Teaching Basic Electrical and Electronic Engineering Courses Using AI and Project-Based Learning to Construct an Inquiry-Based Classroom

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Abstract: The fundamentals of electrical and electronic engineering involve both theoretical and practical components and serve as a foundational course for communication engineering students in subsequent specialized studies. This study focuses on the basic electrical and electronic engineering course and aims to construct an inquiry-based classroom teaching model by integrating artificial intelligence (AI) with project-based learning. AI technologies are embedded into project practice to support students in effectively integrating electrical and electronic engineering knowledge with intelligent technologies. Through project-based learning tasks, such as the design of a cyclic festival lighting system, students are encouraged to identify problems in authentic contexts, conduct experimental investigations for verification, and consolidate knowledge through reflection and summarization. The results indicate that the integration of AI and project-based learning enhances students' understanding of electrical and electronic principles, improves their ability to apply AI technologies, and stimulates learning interest. This teaching model provides a feasible and effective pathway for the implementation of inquiry-based classrooms in electrical and electronic engineering education.

Keywords: artificial intelligence; project-based learning; inquiry-based classroom; electrical and electronic engineering; engineering education

1. Introduction

The course *Basic Electrical and Electronic Engineering* is an essential foundational course for communication engineering students, equipping them with basic circuit knowledge as well as the ability to conduct circuit testing and maintenance. However, in teaching practice, there are problems such as excessive emphasis on theoretical instruction and experimental activities that focus primarily on verification. Although students may master relevant knowledge, their ability to transfer and apply this knowledge to real-world engineering problems is relatively weak, making practical application difficult.

With the development of artificial intelligence (AI), various industries are transforming and upgrading toward intelligent systems, and the education and communication sectors are no exception. This development places higher demands on the teaching of basic electrical and electronic engineering courses, requiring the cultivation of students' abilities to utilize information technologies and engage in independent inquiry. Traditional lecture-based teaching models are no longer sufficient to meet the requirements of cultivating inquiry abilities in modern communication engineering professionals. Inquiry-based classrooms, characterized by student-centered learning and process-oriented instruction, provide a classroom framework centered on problem-based inquiry and evidence-based reasoning [1].

An inquiry-based classroom takes students as the central participants in learning, while teachers play a supportive and guiding role. With teachers' guidance, students are

able to actively explore, discover, and ultimately acquire knowledge. In inquiry-based classrooms, students gradually learn how to identify problems, think critically about problems, and solve problems, thereby establishing their own knowledge systems and learning methods [2].

Inquiry-based classrooms mainly consist of the following stages. First, problems are introduced and hypotheses are proposed. Based on instructional objectives and content, teachers raise thought-provoking and logically structured questions to guide students toward the target knowledge. Second, problem analysis and exploratory verification are conducted. Under teachers' guidance, students engage in independent learning and group collaboration to explore key knowledge points in depth. Through experimental activities and repeated trial-and-error processes, students solve practical problems and gradually form their own cognitive frameworks. Third, reflection, summarization, transfer, and application are carried out. During this stage, students summarize inquiry outcomes and engage in innovation and re-creation based on their learning experiences.

However, the construction of inquiry-based classrooms requires effective instructional methods and appropriate support. The emergence of project-based learning has demonstrated its strong advantages and provides solid support for inquiry-based classroom construction. By organizing students to conduct systematic inquiry around real problems, project-based learning enables the integration of multidisciplinary knowledge through the completion of project tasks. Project-based learning abandons traditional lecture-based instruction, takes students as the main participants, and uses project completion as the guiding principle, thereby providing essential conditions for students' independent inquiry [3].

In summary, this study aims to employ artificial intelligence and project-based learning as teaching approaches to construct an inquiry-based classroom through project tasks, thereby enhancing students' information technology application abilities and independent inquiry capacities.

2. Instructional Design

Based on the inquiry-based classroom model, and using artificial intelligence (AI) and project-based learning as instructional tools, the inquiry-based classroom teaching process is designed into three stages.

2.1. Before class: Problem scenario and hypothesis formulation.

Before class, the teacher creates problem scenarios based on real-world situations and releases the project content. After receiving the project tasks, students, driven by the identified problems, learn relevant knowledge points with the assistance of AI and complete the conceptualization of solutions and the formulation of hypotheses [4].

2.2. In-class activities: Problem analysis and exploratory verification.

The main focus of in-class activities is the practical implementation of projects. Prior to class, students have already developed their project plans. During class, they work in groups to implement these plans. The teacher primarily acts as a facilitator, guiding students through project implementation by posing questions. Meanwhile, students can utilize AI for data analysis and discussion, independently resolving problems encountered during experiments.

2.3. After class: Reflection, summarization, transfer, and application.

After class, students are required to complete self-evaluation and reflection. Based on the data collected and the problems encountered during classroom experiments, students can receive targeted feedback from AI. Using the personalized feedback generated by AI, students conduct self-evaluation and reflection and engage in personalized extension tasks according to their identified problems.

Figure 1 presents the instructional design scheme for the *Electrical and Electronic Engineering* course that integrates AI and project-based learning to construct an inquiry-based classroom. This study takes the "Design of a Cyclic Colorful Light for Festivals" as an example to illustrate the teaching implementation process of constructing an inquiry-based classroom through AI and project-based learning.
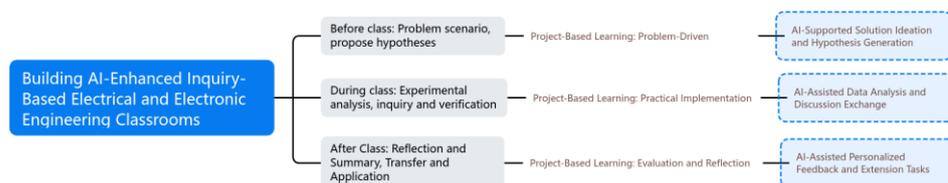
Figure 1. Instructional design framework for constructing an inquiry-based classroom integrating AI and project-based learning.

3. Teaching Implementation Process:

3.1. Before class: Problem scenario, hypotheses are proposed.

In the first stage, considering students' learning situation, teaching objectives, and the interest of learning, this study selected a simple electronic project closely related to daily life-"Design and Implementation of a Cyclic Colored Light for Festivals." The project task was to design and implement a colored light circuit that could periodically and cyclically light multiple LEDs under a given DC power supply, and to analyze and verify the relevant data [5].

Before class, teachers could distribute videos showcasing common recurring decorative lights used in festivals, clarifying the project task and the requirements for designing a small recurring decorative light. After assigning the task, students were required to design their solutions in groups. Students could utilize AI assistants to access relevant information and supplement their knowledge. For example, students could use AI to look up the basic structure of common cyclic decorative light circuits, the functions of the involved components, and possible implementation schemes. Based on this, group members could discuss their ideas and the knowledge they had learned to form a preliminary design plan.

In this experiment, students proposed three feasible solutions:

1) Solution 1: Uses an NE555 timer without an oscillator in combination with a counter. The 555 provides clock pulse signals, the counter counts the pulse signals, and outputs a high-level signal to light up the LEDs.

2) Solution 2: Uses an NE555 timer without an oscillator in combination with a register. The 555 provides pulse signals, and the highest bit output of a bidirectional shift register serves as the input signal to the control terminal of another bidirectional shift register, thus achieving the cyclical on/off state of the LEDs.

3) Solution 3: Uses a microcontroller combined with LEDs and resistors to construct a circuit. The program is programmed into the microcontroller to control the lighting pattern. If the lighting pattern needs to be changed, only the program needs to be modified.

After completing the design, students could use software to simulate the circuit to further determine the rationality of the circuit design.

The pre-class stage did not emphasize the correctness of the plan. The purpose of the design was to enable students to have a preliminary understanding of the project and a sense of the problem before entering the classroom, so as to cultivate students' sense of inquiry and lay the foundation for subsequent experimental investigation.

3.2. In-class activities: Problem analysis, exploration, verification

The in-class phase is the core of the inquiry-based classroom, with teaching activities unfolding primarily through project implementation [6]. The teacher first explains experimental safety and usage guidelines. Subsequently, students work in groups to build circuits based on the hypotheses proposed before class, and observe and record the sequence of LED lights turning on and off. When experimental results differ from expectations, students can use AI to analyze circuit phenomena and troubleshoot problems independently, without relying on the teacher.

For example, in this experiment, students using Solution 2 encountered issues where all LEDs were lit simultaneously or the lights flickered irregularly. After reporting these phenomena to the AI, students were able to troubleshoot the problems. The issue of all LEDs being lit was caused by leaving unnecessary register inputs floating, and the irregular flickering of lights was caused by an unstable clock signal. These examples represent only some of the problems encountered in students' experiments and do not necessarily indicate the causes of any single fault.

For groups that had completed their circuit construction, the teacher encouraged comparisons among their solutions to identify the optimal design. During this process, group members could use AI to compare and analyze the advantages and disadvantages of different schemes and select the best one. This classroom practice employed three different implementation schemes. After stimulating discussion and comparison among groups, the following conclusions were drawn:

1) Solution 1: Uses an NE555 timer without an oscillator in combination with a counter. This scheme has a simple circuit and is easy to build, but the lighting effect is relatively simple. Achieving complex lighting patterns is difficult with this approach.
2) Solution 2: Uses an NE555 timer without an oscillator in combination with a register. This approach is suitable for creating flowing and back-and-forth LED sequences, but also suffers from the limitation of relatively simple lighting effects.
3) Solution 3: Uses a microcontroller combined with LEDs and resistors to construct the circuit. This approach uses a program to control the changing patterns of the lighting effect, so modifying the pattern is relatively easy, requiring only adjustments to the program. However, it demands a higher level of prior knowledge from students, creating an entry barrier, and beginners may find it difficult to quickly implement the circuit.

After comparing the schemes, groups could further optimize and improve their circuits based on their specific situations.

Throughout the lesson, the teacher acted as a guide and facilitator, directing students' attention to the circuit's working mechanisms rather than merely its operational aspects by posing key questions such as "Why does a certain branch light up first?" and "How do parameter changes affect the cycle frequency?" Group discussions and presentations fostered students' spirit of inquiry and their ability to share experiences.

3.3. After class: Reflection, summary, and application.

Post-lesson reflection and summarization included reflections at the knowledge, process, and methodological levels. Each group was required to review the project implementation process after the experiment and produce a project learning report. The project learning report included the circuit principles, experimental phenomena and debugging experience, existing problems, and directions for improvement, corresponding to knowledge-level, process-level, and methodological-level reflections [7].

- Knowledge-level reflection involved verifying whether the circuit's working principles were truly understood.
- Process-level reflection involved identifying the causes of failures based on experimental phenomena and debugging experience.

- Methodological-level reflection involved considering whether the steps taken were scientifically sound by analyzing existing problems and possible improvements.

During the reflection and summarization process, students could use AI to summarize key knowledge points and reflect on problems encountered during the experiment as well as possible improvements. At the same time, the teacher assigned extension tasks, such as "Implement a model of a simple two-point traffic light" or "Design a status indicator light for a household appliance." By changing the problem scenario, students were encouraged to apply the design ideas of festival cyclic colored lights to other sequential control problem scenarios, enhancing their ability to optimize and adjust circuit structures, and deepening their understanding of circuit principles [8].

Through post-lesson reflection and application, students not only consolidated their knowledge but also gradually developed an inquiry-based learning habit of "posing questions-analyzing problems-solving problems."

4. Implementation and Results

4.1. Inquiry-Based Classrooms Promote the Improvement of Students' Inquiry Abilities

The inquiry-based classroom developed in this study integrates project tasks throughout the entire teaching process, forming a learning path with "proposing questions-analyzing questions-solving questions-reflecting and applying" as the main thread.

In the pre-class stage, students were guided to raise questions and formulate hypotheses around the specific project of "designing a cyclical colored light for festivals" by creating a practical scenario closely related to daily life. This scenario not only effectively reduced the difficulty of learning but also provided students with a sense of familiarity, which in turn stimulated their interest in learning. Supported by their existing basic knowledge of electrical and electronic engineering, students were able to independently research and speculate on the implementation of the cyclical flashing of the colored lights using AI, thus developing preliminary circuit design ideas. This process cultivated students' inquiry-based thinking and circuit construction abilities [9].

During the in-class stage, teachers organized students to conduct experimental analysis and inquiry-based verification. Students continuously verified and revised their design schemes through circuit construction, parameter adjustment, and phenomenon observation. Groups could compare and discuss different design approaches and experimental results, allowing students to examine problems from multiple perspectives and deepen their understanding of the circuit's working principles. Through the analysis of experimental data and the verification of results, students gradually achieved a cognitive shift from "phenomenon observation" to "mechanism explanation."

In the post-class stage, students systematically reviewed the project implementation process through reflection, summarization, and application. On one hand, they summarized the key knowledge points and technical aspects of the holiday-themed cyclical colored light circuit; on the other hand, through extended tasks, they applied the principles they had learned to the design of other simple electronic circuits, thereby reconstructing and consolidating their knowledge. This process facilitated students' transformation from "completing tasks" to "understanding principles and applying them flexibly," forming a complete closed loop of inquiry-based learning.

Overall, the implementation of inquiry-based classrooms effectively promoted students' transition from passive recipients of knowledge to active problem solvers. While improving students' experimental analysis skills, problem-solving ability, and knowledge transfer capacity, it also enhanced their enthusiasm and initiative in participating in learning [10].

4.2. The Teaching Model Combining AI and Project-Based Learning Provides an Effective Way to Construct Inquiry-Based Classrooms

In the practice of inquiry-based classrooms, the integration of artificial intelligence (AI) and project-based learning provides an effective approach to teaching activities. Project-based learning, with its task-oriented approach, offers clear learning objectives and practical scenarios, while AI technology plays a supportive role in information acquisition, solution generation, and data analysis, effectively enhancing the efficiency and quality of inquiry-based classroom implementation [11].

At the teacher level, instructors become planners and facilitators of learning activities. With the assistance of AI tools, teachers can efficiently design project tasks, create problem scenarios, and integrate teaching resources. For example, in the cyclical colored light project, teachers could use AI in advance to generate multiple circuit design ideas and related problem scenarios, and subsequently process and reorganize the generated content to better align with teaching objectives and students' cognitive levels. Based on this, and guided by well-designed questions, students could gradually conduct in-depth exploration, preventing the inquiry process from becoming overly simplistic or deviating from the teaching focus.

At the student level, AI effectively supports project-based learning. Before class, students can proactively study circuit principles and component functions using AI, developing a solid understanding of new knowledge, enhancing learning autonomy, and improving both learning efficiency and the efficiency of teacher instruction. During in-class experiments and discussions, when groups explore their design schemes to identify optimal solutions, AI can serve as a reference tool, providing diverse perspectives to help students compare, analyze, and make informed judgments. In the post-class stage, students, with AI assistance, complete lab reports, summarize reflections, and design extension tasks, thereby consolidating learning outcomes and deepening their understanding.

Through the combined use of AI and project-based learning, inquiry-based classrooms are effectively strengthened in all stages-pre-class, in-class, and post-class. This approach not only reduces teachers' workload and enhances teaching efficiency, but also develops students' inquiry skills and self-directed learning abilities. Practical experience has verified that this teaching model facilitates the construction of student-centered, project-based, inquiry-oriented electrical and electronic classrooms, achieving an organic integration of information technology and the cultivation of inquiry abilities [12].

5. Conclusion

In the teaching of basic electrical and electronic engineering, the innovative integration of AI and project-based learning to construct an inquiry-based classroom has demonstrated significant educational benefits. This approach not only implements a student-centered teaching philosophy but also effectively enhances students' inquiry abilities and their capacity to apply information technology. By creating learning scenarios based on real-world problems, teachers guide students through the processes of hypothesis formulation, experimental analysis, and result verification, fostering autonomous learning and deep understanding of knowledge.

In teaching practice, AI and project-based learning provide effective support and feasible solutions for constructing inquiry-based classrooms, gradually improving students' self-directed learning abilities. Through experimental inquiry and reflective summarization, students' inquiry skills are continuously developed, while knowledge learned in one context is transferred and applied to others.

Overall, the exploration and implementation of inquiry-based classrooms based on AI and project-based learning not only strengthen students' initiative and depth of inquiry but also enhance overall classroom teaching effectiveness. This model provides a referable

framework for the reform of electrical and electronic engineering education and highlights the potential of integrating technological tools with pedagogical innovation to cultivate competent, independent learners.

References

1. P. Nagaraj, and M. Raja, "Effect of Inquiry-based Learning on Engineering Students as Collaborative Approach in Problem-Solving and Research for Formal Language Automata Course," *Journal of Engineering Education Transformations*, pp. 23-29, 2025. doi: 10.16920/jeet/2025/v38is2/25004.

2. B. Archer-Kuhn, Y. Lee, S. Finnessey, and J. Liu, "Inquiry-based learning as a facilitator to student engagement in undergraduate and graduate social work programs," *Teaching & Learning Inquiry*, vol. 8, no. 1, pp. 187-207, 2020. doi: 10.20343/teachlearninqu.8.1.13.

3. F. Chen, and G. Chen, "Learning analytics in inquiry-based learning: a systematic review," *Educational technology research and development*, pp. 1-31, 2025. doi: 10.1007/s11423-025-10507-9.

4. S. Tang, "Technology and Education Integration": Reconstruction of the Path of Classroom Teaching Empowered by Intelligent Educational Technology--The Rational Use of Artificial Intelligence Based Technology," In *2025 5th International Conference on Artificial Intelligence and Education (ICAIE)*, May, 2025, pp. 845-851. doi: 10.1109/icaie64856.2025.11158652.

5. X. Tang, D. Xu, X. Ma, S. Zhang, and J. Diao, "An exploration of project-based learning supported by artificial intelligence," in *Proc. 2024 5th Int. Conf. Big Data Informatization Educ. (ICBDIE 2024)*, May 2024, pp. 220–230. Atlantis Press. doi: 10.2991/978-94-6463-417-4_20.

6. S. Bell, "Project-based learning for the 21st century: Skills for the future," *The clearing house*, vol. 83, no. 2, pp. 39-43, 2010. doi: 10.1080/00098650903505415.

7. H. P. Learn, *Brain, Mind, Experience, and School*, Committee on Developments in the Science of Learning, National Research Council, The National Academies Press, 2000, pp. 14–15. ISBN: 9780309070362.

8. G. D. Furman, "Enhancing engineering education: The role of artificial intelligence in personalizing learning and outcomes," In *2024 4th International Conference on Big Data Engineering and Education (BDEE)*, August, 2024, pp. 61-65. doi: 10.1109/bdee63226.2024.00018.

9. C. E. Hmelo-Silver, "Problem-based learning: What and how do students learn?," *Educational psychology review*, vol. 16, no. 3, pp. 235-266, 2004. doi: 10.1023/b:edpr.0000034022.16470.f3.

10. W. Hung, "Problem-based learning: a learning environment for enhancing learning transfer," *New Directions for Adult & Continuing Education*, vol. 2013, no. 137, 2013. doi: 10.1002/ace.20042.

11. J. L. Kolodner, P. J. Camp, D. Crismond, B. Fasse, J. Gray, J. Holbrook, and M. Ryan, "Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice," *The journal of the learning sciences*, vol. 12, no. 4, pp. 495-547, 2003. doi: 10.1207/S15327809JLS1204_2.

12. B. P. Woolf, "Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning," *Morgan Kaufmann*, 2010. ISBN: 9780123735942.