Exploration and Practice of Industry-Education Integration Specialized Discussion Courses in the Training of Environmental Engineering Professionals

Bin Dong[1,2,*], Hui Wang[1,a], Tingting Xiao[1,b], Yunhui Zhang[1,c], Chen Zhang[3,d], Xiaojie Sun[2,e], Honghu Zeng[2,f]

[1]College of Environmental Science and Engineering, Tongji University, Shanghai 200092, China
[2]College of Environmental Science and Engineering, Guilin University of Technology, Guilin 541004, China
[3]School of medicine, Tongji University, Shanghai 200092, China

[*]tjdongb@163.com; [a]18857066440@163.com; [b]xiaott@tongji.edu.cn; [c]yunhuizhang@tongji.edu.cn; [d]13664270982@163.com; [e]sun-xiaojie@glut.edu.cn; [f]zenghonghu@glut.edu.cn

Abstract. The conventional classroom teaching model struggles to meet the requirements for cultivating outstanding engineers in the field of environmental engineering under the Outcome-Based Education (OBE) philosophy in the new era. In addition to the existing core courses, the incorporation of seminar discussions as a teaching mode to reinforce students' knowledge dissemination has been applied in multiple universities. This paper, based on the analysis of the OBE goals for cultivating outstanding engineers and the existing shortcomings in the training of talents in the environmental engineering discipline, innovatively proposes the utilization of teacher-industry expert collaborative seminars based on open-ended problems. Through multiple rounds of debates involving two student groups, this approach aims to enhance students' application of professional knowledge and engineering argumentation skills, effectively tap into students' innovative capabilities, and achieve interactive improvement between teachers and students as well as a sustained enhancement in teaching quality. Practical evidence indicates that students participating in these discussion seminars show significant improvements in academic performance, participation in academic competitions, and pursuit of postgraduate studies.

Keywords: OBE philosophy; Outstanding engineers; Specialized seminar discussions; Environmental engineering

Y. Kuang et al. (eds.), *Proceedings of the 2024 5th International Conference on Education, Knowledge and Information Management (ICEKIM 2024)*, Atlantis Highlights in Computer Sciences 22,
https://doi.org/10.2991/978-94-6463-502-7_49

1 Introduction

1.1 Identification of Shortcomings in the Training of Professionals in Environmental Engineering Based on the OBE Goals for Cultivating Outstanding Engineers

The concept of Outcome-Based Education (OBE), also known as competency-based education, goal-oriented education, or demand-oriented education, plays a central role in the field of engineering education accreditation [1]. These requirements encompass engineering knowledge, problem analysis, design/development of solutions, research, use of modern tools, engineering and society, environmental and sustainable development, professional ethics, individual and teamwork, communication, project management, and lifelong learning.

In accordance with the OBE philosophy, the Ministry of Education, in collaboration with the Chinese Academy of Engineering, issued the "Common Standards for the Training Program of Outstanding Engineers". These standards outline the goals for cultivating outstanding engineers: oriented towards the industry, the world, and the future. The objective is to cultivate a significant number of high-quality engineering and technical professionals with strong innovative capabilities, capable of meeting the needs of economic and social development. This initiative aims to establish a solid human resources advantage to support the construction of an innovative nation, achieve industrialization and modernization, enhance China's core competitiveness, and bolster overall national strength [2].

The field of environmental engineering is a highly interdisciplinary domain, integrating knowledge from various disciplines such as engineering, chemistry, biology, and earth sciences to comprehensively understand and address environmental issues. This discipline emphasizes on practical engineering skills and applications, such as water and wastewater treatment, air pollution control, and waste management. It also prioritizes the dual carbon strategy and sustainable development [3]. Aligned with the goals and standards for cultivating outstanding engineers, as well as the 12 competency requirements outlined by the China Engineering Education Accreditation Association for engineering disciplines, the training of environmental engineering professionals as outstanding engineers emphasizes the development of four key abilities: information acquisition, critical thinking, innovation, and practical application.

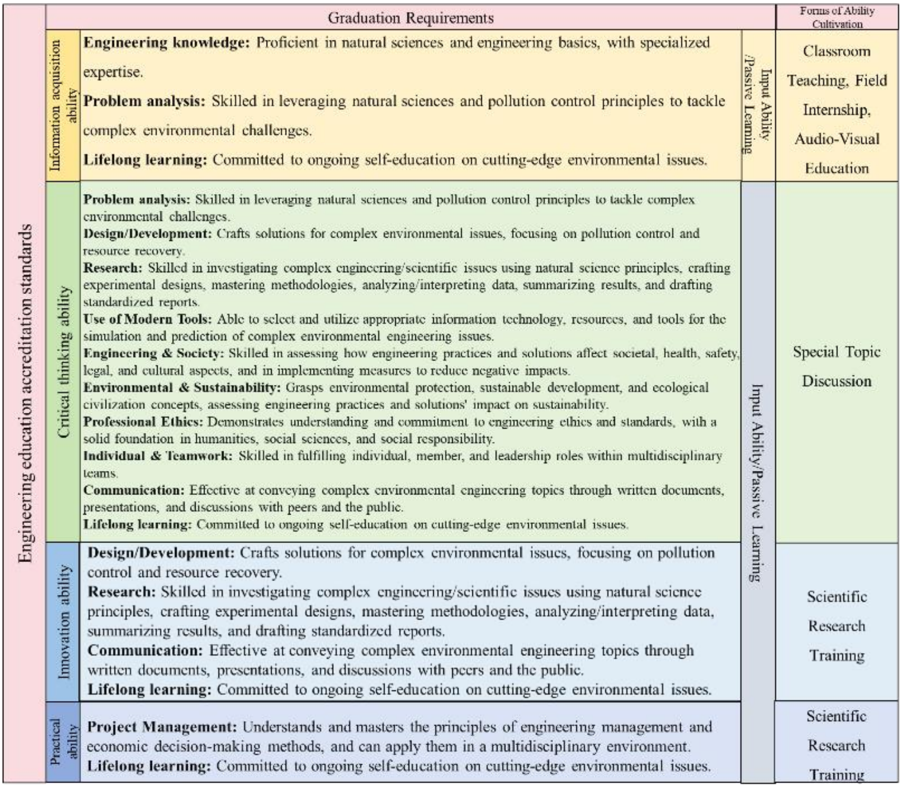

Fig. 1. Cultivation of four key competencies based on graduation requirements outlined in engineering education accreditation

As shown in Fig. 1, the cultivation of outstanding engineers in environmental engineering relies on four key competencies. Firstly, information acquisition emphasizes students' ability to effectively identify, assess, and utilize information resources in a rapidly changing technological environment. This involves achieving competencies in engineering knowledge, the use of modern tools, and professional ethics. Secondly, critical thinking is essential for environmental engineering students to analyze problems critically, especially in dealing with complex environmental issues. This competency encompasses problem analysis, engineering and society, environmental and sustainable development, and communication. Thirdly, innovation underscores the ability of environmental engineering students to propose innovative solutions to complex environmental problems, crucial for addressing today's increasingly severe environmental challenges. This competency involves achieving requirements in designing/developing solutions, research, and lifelong learning. Finally, practical application emphasizes the importance of applying theoretical knowledge to real-world situations, enhancing students' professional skills and deepening their understanding of the environmental engineering field. This competency includes professional ethics, individual and teamwork, and project management. These competencies collectively form the cornerstone of cultivating outstanding engineers in environmental engineering, providing them with the necessary tools and mental frameworks to adapt to and promote sustainability in their future careers.

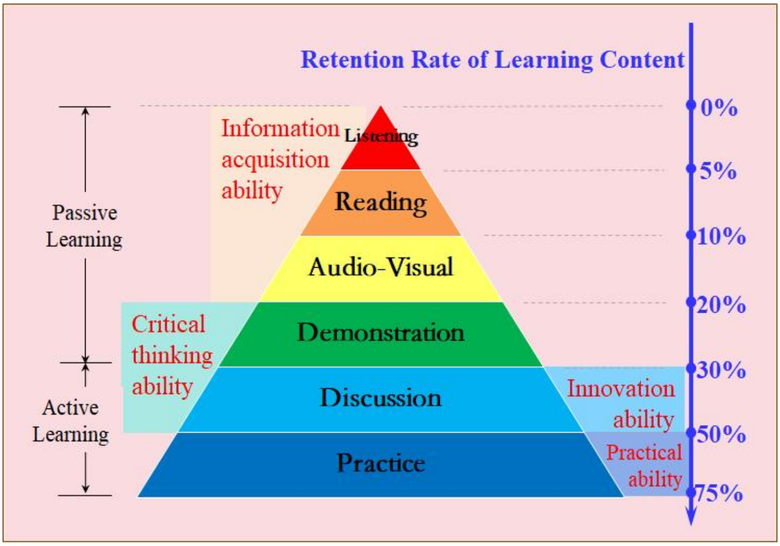

Fig. 2. Division of Four Key Competencies Based on the Learning Pyramid Theory

In 1946, American scholar Edgar Dale introduced the "Learning Pyramid Theory," a numerical representation illustrating the differences in learning outcomes and average retention rates for various learning methods, indicating how much content learners can remember after two weeks [4]. As depicted in Fig. 2, different learning methods yield different educational effects. Traditional teaching falls under passive learning, where students retain approximately 20% of the content through methods such as lectures, reading, and audio-visual aids. These three teaching processes primarily cultivate students' information acquisition abilities. The final step of passive learning, demonstration, and the first step of active learning, discussion, collectively enhance students' critical thinking skills, increasing the retention rate to 50%. Critical thinking holds a crucial position in the field of education. It serves as a manifestation of students' information acquisition abilities, forms the foundation for fostering innovation and practical skills, and marks a pivotal step in transitioning from passive to active learning. Therefore, the key to improving teaching effectiveness lies in changing the learning approach-shifting from passive to active learning to stimulate students' enthusiasm and initiative in the learning process. In this context, teachers play the roles of knowledge guides and observers, guiding students to identify and solve problems during the learning process.

2 The Development of Specialized Discussions Courses

The lack of cultivation of speculative ability constitutes a crucial factor constraining the enhancement of innovative and engineering practical capabilities among students majoring in environmental engineering. Scientifically designed thematic discussions emerge as a vital means to effectively cultivate and elevate students' speculative abilities, playing a pivotal supporting role in achieving the 12 outcome-based education (OBE) competency requirements for students in the field of environmental engineering.

The roots of the discussion-based teaching method can be traced back to the ancient Greek philosopher Socrates, who pioneered the "Socratic method" during instruction. This approach diverges from the conventional model of direct knowledge transmission from teacher to student. Instead, it involves guiding students through collaborative discussions and debates, fostering continuous deep thinking and exploration, ultimately leading to the derivation of correct answers [5]. In 1953, Polani applied group discussion techniques to medical courses and affirmed the beneficial and effective nature of free group discussions for both students and teachers [6]. North American educators introduced the concept of Problem-Based Learning (PBL) in the format of discussion classes. PBL is a student-centered, inquiry-based teaching model where students form learning groups and acquire knowledge by solving problems [7]. Under the guidance of the teacher, students engage in self-directed learning, group discussions, and problem-solving to ultimately acquire new knowledge.

Research on discussion-based teaching in China started later than in the West, but in recent years, various disciplines and fields have achieved significant theoretical and practical research results in the application of discussion-based teaching methods. Jiao et al. optimized the teaching process of medical physiology by combining micro-lectures and thematic discussions [8]. The process involves teachers posting weekly micro-lecture content, assignments, discussion topics, and outlines on the platform. Students first self-study the micro-lectures and complete assignments, then prepare materials based on discussion topics and engage in group discussions. The teacher concludes the session and adjusts strategies accordingly. This method enhanced students' self-learning abilities and teamwork, receiving recognition from 90% of the students. Wang et al. in the context of the new engineering education, established a comprehensive teaching model for discussion classes on industrial wastewater pollution prevention and control [9]. In this teaching model, students take the lead, forming teams (3-4 members) and selecting topics freely. They conduct in-depth research and analysis over one month, followed by presentations, exchanges, and in-depth discussions. Lin et al. implemented specific measures to increase students' active participation and awareness during the teaching process [10]. These measures include assigning 6-8 discussion topics in advance, requiring students to independently conduct literature reviews, organize data, and create PowerPoint presentations. Classes organize review teams under the guidance of the teacher to evaluate the presentations using a four-level assessment. Subsequently, students form teams based on the topics, further improving the presentations. The discussion class includes presentation and questioning segments, led by students, with the review team and teachers serving as judges. Evaluation criteria include the quality of the presentation and student interaction. After the course, students submit detailed self-assessment forms, covering literature reviews, presentation quality, and discussion class interactions, serving as the basis for assessing students' performance in discussion classes. This approach effectively stimulates students' enthusiasm for active participation, enhancing their awareness as active learners. As shown in Fig. 3, the addition of thematic discussion classes has, to some extent, addressed the deficiency in competency development in the field of environmental engineering.

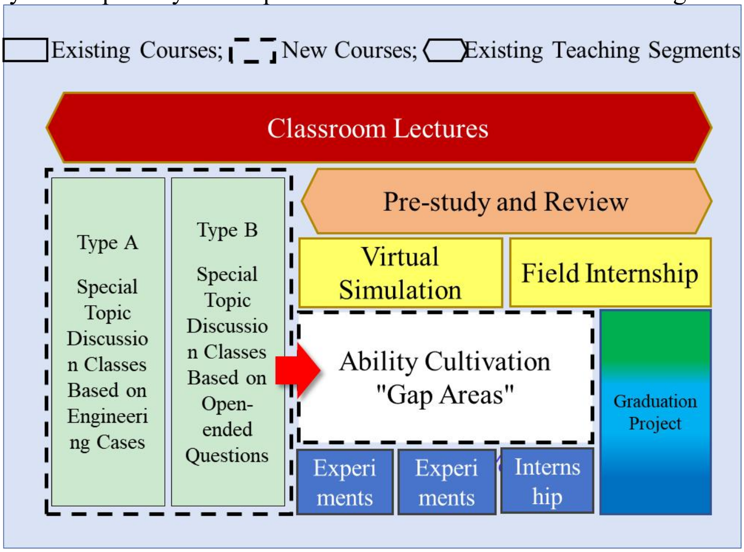

Fig. 3. Specialized discussions courses fill the gaps in capability cultivation in the environmental engineering major

3 Specialized Discussions Courses for Environmental Engineering Majors Integrating Industry and Education

Based on the identified deficiencies in competency development in the field of environmental engineering, and drawing from the theoretical and practical exploration results of thematic discussion course teaching, as well as the distinctive features of environmental engineering, an innovative thematic discussion course has been designed. This course involves collaborative efforts between teachers and industry experts, focusing on open-ended problems. The discussion course is tightly aligned with China's Yangtze River conservation strategy, guiding students to actively engage in serving the national strategic interests. It introduces a series of open-ended questions related to pollution control, resource utilization, and the construction of future pollution facilities. To enhance student participation, these questions are framed as debate topics. Students are divided into two groups for corresponding data preparation and in-class debates. Senior experts from key enterprises are invited to co-guide the debates with the teachers. This approach encourages students to actively apply their acquired professional knowledge during debates, gaining a comprehensive understanding of the advantages and disadvantages of various technological processes and real-world engineering issues. It stimulates students to actively seek solutions to problems and improves their teamwork and collaboration skills. The overarching goal is to not only address the deficiencies in competency development but also to instill in students a practical and strategic perspective within the context of national environmental protection initiatives. The specific workflow arrangement is shown in Fig. 4.

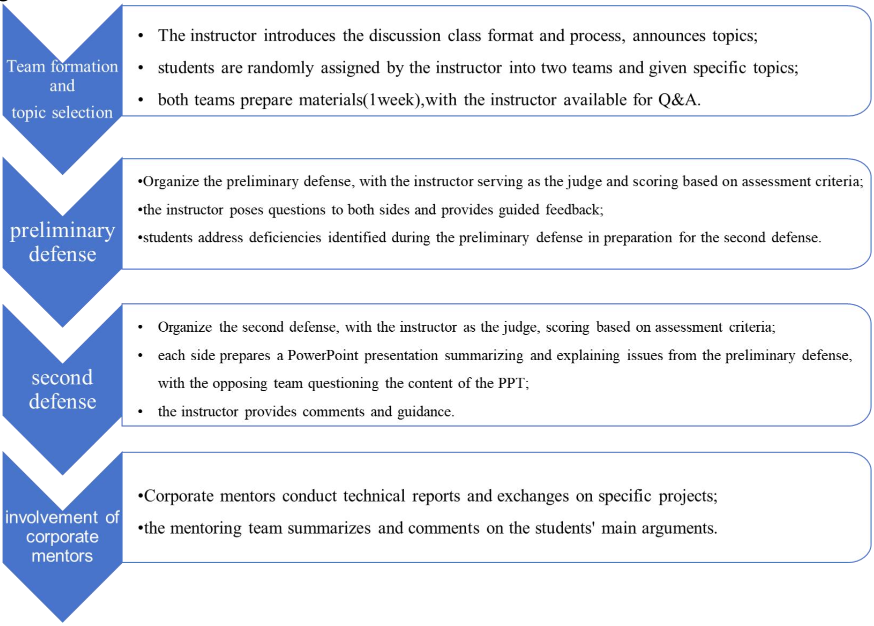

Fig. 4. The process of a debate-style thematic seminar on industry-education integration.

Week 1: Introduction of Topics (Teachers introduce the domestic and international background of selected topics) and Team Formation for Students; Student teams prepare materials for one week, with teacher guidance and clarification sessions. Week 2: Initial Debate (Each student is required to speak; the teacher team poses questions to both sides and provides guidance and feedback). Week 3: Second Debate (Both sides organize a PowerPoint presentation summarizing and elaborating on the issues raised in the initial debate; the opposing team questions the presentation, and the teacher team provides feedback and guidance). Week 4: Industry mentors will present technical reports and engage in discussions specific to the projects. The mentor team will summarize and evaluate the students' main arguments. The thematic seminar proposed in this study spans a total of 8 class hours (4 weeks), based on the fundamental knowledge of the core courses "Water Pollution Control Engineering" and "Solid Waste Treatment and Disposal" in the Environmental Engineering major. Possible topics related to these two core courses are listed in Table 1.

Table 1. The specialized seminar discussion topics

Water Pollution Control Engineering	Solid Waste Treatment and Disposal
Does the further enhancement of urban sewage discharge standards from Class A to Class A+ contribute to environmental friendliness and sustainability?	Is the primary characteristic of sludge a resource attribute or a pollution attribute?
The advantages and disadvantages of using treated sewage for agricultural irrigation.	Is the main bottleneck for the land utilization of organic solid waste from daily sources in engineering technology or policy management?
Is the primary source of water pollution in China's urban water environment from urban drainage pipelines or from sewage treatment plant discharges?	From a holistic perspective of the entire chain, can the collection and treatment of classified waste significantly reduce carbon emissions compared to the previous mixed collection, mixed transportation, and waste incineration process?

4 The Assessment and Practical Aspects of the Industry-education-integrated Thematic Seminar in the Environmental Engineering Major

The assessment and evaluation system plays a guiding role in the implementation of teaching, and teaching is inseparable from assessment. Through continuous evaluation during teaching, teachers can analyze the learning situation, diagnose the degree to which students have achieved course objectives, and strategically optimize teaching methods to promote better student development. The assessment and evaluation system proposed in this paper for the teacher-industry expert integrated thematic seminar, based on open-ended questions, primarily consists of three components: written exam scores in specialized courses, the number of awards won in academic competitions, and the percentage of the class pursuing postgraduate studies.

4.1 Academic Performance in Specialized Courses

Comparisons were made between the final exam scores of students in classes with and without the teacher-industry expert integrated thematic seminar based on open-ended questions, as shown in Fig. 5. Under the same training method and using the same exam paper, the average score for classes with the thematic seminar was 79, with the highest score being 94 and the lowest being 61, all meeting the passing criteria. In contrast, the average score for classes without the thematic seminar was 69, with the highest score being 86 and the lowest being 54. Additionally, two students in this group failed the specialized exam. Therefore, based on the written exam scores, it can be concluded that the debate-style thematic seminar with industry-education integration improved knowledge retention by 14%.

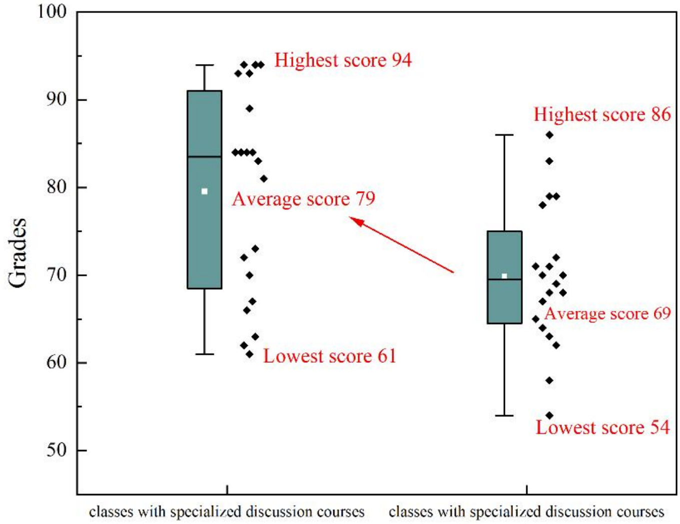

Fig. 5. Academic performance in written exams for specialized courses.

4.2 Number of Awards Won in Academic Competitions

Based on the assessment results of the industry-education-integrated debate-style thematic seminar mentioned above, and considering the feedback from industry mentors, 4-8 outstanding talents are selected to participate in research training, innovation and entrepreneurship competitions, aiming to further cultivate talents with a focus on technological innovation and practical entrepreneurship. Currently, by integrating theory and practice, combining academic and industry training modes (as shown in Fig. 6), not only can students' professional skills be effectively improved, but outstanding engineering talents with an innovative spirit and practical abilities can also be nurtured, meeting the demands of modern society and economic development.

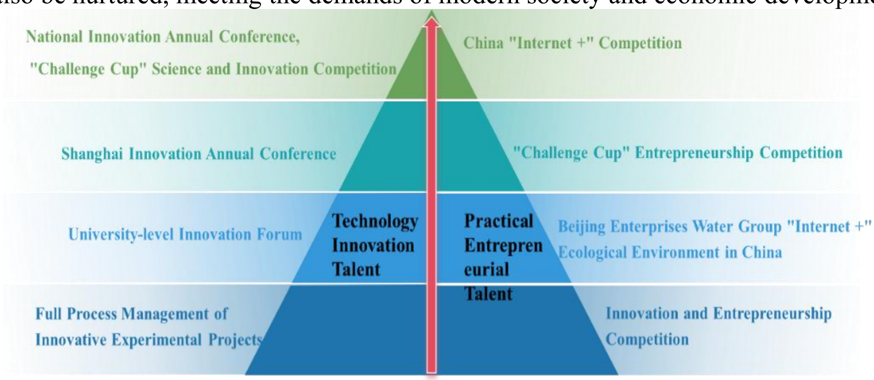

Fig. 6. Innovation and Entrepreneurship Talent Development System

By comparing, we conducted a statistical analysis on the number and quality of awards obtained by students participating in various academic competitions in classes with and without the teacher-industry expert integrated thematic seminar based on open-ended questions. In the classes with the seminar, students, as primary members, participated in three teams for academic competitions, totaling 8 individuals, and achieved a total of 12 awards. Specifically, they won 3 times in national-level competitions, 6 times in municipal-level competitions, and 3 times in university-level competitions. On the other hand, in classes without the seminar, students, as primary members, participated in two teams for academic competitions, totaling 5 individuals, and obtained a total of 8 awards. Among these, they won 5 times in municipal-level competitions and 3 times in university-level competitions. Overall, it can be concluded that the number of students who are primary participants in academic competitions is higher in classes where the teacher-industry expert integrated thematic seminar is based on open-ended questions. Moreover, the number and quality of awards obtained are superior compared to classes without the thematic seminar.

4.3 The Percentage of Students Pursuing Postgraduate Studies in the Class

To further analyze the attainment of students' comprehensive engineering abilities in classes with the teacher-industry expert integrated thematic seminar based on open-ended questions, the number of students pursuing postgraduate studies is also included as an assessment indicator. Pursuing postgraduate studies represents a strong curiosity and solid foundation in the field of study. In classes with the thematic seminar, 60% of students pursue postgraduate studies or further education abroad, which is higher than the classes without the thematic seminar (35%). Therefore, the new model proposed in this paper, the teacher-industry expert integrated thematic seminar based on open-ended questions, can effectively enhance the quality of professional talent development.

5 Conclusion

As a crucial component of modern educational methods, thematic seminar courses have demonstrated significant effectiveness and achievements, providing profound insights for future educational reforms. The teacher-industry expert integrated thematic seminar, based on open-ended questions proposed in this paper, transforms the traditional format of seminars by incorporating debates. This approach ignites students' competitiveness and stimulates their curiosity about professional courses. This approach enhances students' mastery of fundamental knowledge and their ability to analyze problems using this knowledge. It facilitates in-depth research and a deeper understanding of specific topics, promoting the development of innovative thinking. Simultaneously, students are trained to effectively use modern tools to predict and design solutions for known or unknown environmental issues. Through discussions, students learn to express their viewpoints clearly and develop the skills of listening, understanding others' perspectives, and enhancing their teamwork abilities. The involvement of industry mentors in guiding and evaluating topics and professional knowledge elevates the discussions from both engineering and practical perspectives. It encourages students to think about problems from engineering and societal standpoints, fostering a profound understanding of the principles of sustainable environmental development. The proposed format of the thematic seminar aligns with the requirements for cultivating the 12 competencies of an excellent engineer under the OBE (Outcome-Based Education) philosophy. Experimental evidence indicates that classes with the teacher-industry expert integrated debate-style thematic seminar exhibit improved academic performance in specialized courses, higher participation and success rates in academic competitions, and a larger percentage of students pursuing postgraduate studies or further education abroad.

In summary, the teacher-industry expert integrated thematic seminar based on open-ended questions has not only achieved significant results in enhancing students' academic capabilities but, more importantly, has played a crucial role in fostering students' critical thinking, practical skills, innovative thinking, and overall qualities. This approach provides valuable guidance and insights for shaping the direction of future education, particularly in cultivating outstanding engineers with comprehensive development to meet the requirements of the modern era.

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