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# BOARD #169: The 5AX Design Model of General Engineering Courses for Graduate Student with A Professional Degree Based on Authentic Learning

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# The 5AX Design Model of General Engineering Courses for Graduate Student with A Professional Degree Based on Authentic Learning

**Abstract:** General engineering courses play a critical role in developing future engineers capable of navigating complex systems and solving real-world engineering problems. A defining feature of these courses is their emphasis on authenticity. Grounded in authentic learning theory, this study proposes the 5AX design model for postgraduate-level general engineering courses. The model incorporates five key activities: adapting to authentic engineering scenarios, experiencing complete industrial processes, completing authentic engineering tasks, conducting authentic engineering collaborations, and evaluating the authentic value of engineering. Using the course *Advanced Engineering Cognition and Practice* at Zhejiang University's Engineering School as a case study, this paper examines how the 5AX model is implemented in practice. The case reveals four distinct features: constructing diverse scenarios for authentic learning, integrating the complete industrial process into course design, enhancing access to interdisciplinary resources, and adopting assessment methods that highlight teamwork and the real-world value of projects. The findings suggest that this model effectively supports the development of interdisciplinary knowledge, teamwork, systems thinking, engineering practice, and industrial awareness among postgraduate students. This study offers valuable insights for shaping general engineering courses in professional engineering graduate education.

**Keywords:** Professional General Courses; Authentic Learning; 5AX Course Model; Project-based Learning; Master of Engineering

## INTRODUCTION

In the era of Industry 4.0, engineering practice has become increasingly integrated and systematized (Xu et al., 2018). In response, universities worldwide are advancing reforms in engineering education and exploring interdisciplinary approaches to talent cultivation. Since 2017, China has witnessed a significant push toward developing emerging engineering education (Zhao et al., 2018). Curriculum design plays a central role in these efforts, as the structure and coherence of course offerings directly influence the quality of engineering training. As part of this reform, a growing number of interdisciplinary general engineering courses tailored to postgraduate education have been introduced. These courses bridge traditional general education and specialized engineering training, serving as a key platform for fostering the holistic development of professional engineering graduate students (Gallagher & Savage, 2023). However, despite their growing presence, such courses often lack clearly defined characteristics and practical design frameworks. Consequently, several challenges persist—such as insufficient integration of comprehensive engineering elements, misalignment between course content and industry needs, rigid teaching methods, and limited student engagement.

This study addresses two key research questions: (1) What are the core characteristics of general engineering courses designed for postgraduate students pursuing professional engineering degrees? (2) How can these courses be effectively designed to embody and deliver these core characteristics? To answer these questions, the paper first conducts a literature review to identify the defining features of such courses. Based on these insights, a course design model is proposed. The model is then applied and examined through a case study of the postgraduate course *Advanced Engineering Cognition and Practice* offered by the College of Engineers at Zhejiang University. This case serves to illustrate the practical implementation of the model and evaluate its effectiveness in fostering professional competencies among engineering graduate students.

## LITERATURE REVIEW

### *General Engineering Courses*

The relationship between general and professional education has long been a central concern in university education reform. Currently, three prevailing perspectives exist. The first views general education as a complement to professional education, providing students with knowledge and skills beyond their disciplinary boundaries. In this view, general and professional education function as parallel systems. A second perspective sees general education as an extension of professional education—broadening its overly specialized focus and enhancing its adaptability. Here, general education is considered a subordinate element within the overarching structure of professional education. The third position regards general education as the intellectual foundation and guiding force of professional education, arguing that the latter should be shaped by the principles of the former (Chen X.Y., 2006). Despite these differences, scholars widely agree that general education must achieve both breadth and depth—enabling students to explore multiple disciplines while also engaging deeply in at least one field (Wu R.L. et al., 2024). General courses represent the practical implementation of general education and are well established at leading global universities, typically spanning both natural sciences and the humanities and social sciences (Qi S.Y. et al., 2022).

At the same time, rapid technological advances and industrial transformations have redefined the landscape of engineering. Traditional disciplines are evolving into interdisciplinary platforms that integrate new energy, information technology, artificial intelligence, transportation, and more. As a result, engineering curricula must also shift from single-discipline frameworks to interdisciplinary knowledge systems. For instance, postgraduate students in vehicle engineering frequently find that breakthroughs in their field are increasingly driven by technologies from electronics, control systems, computing, and software engineering. Yet, their current curriculum often lacks adequate coverage of these areas, leaving a gap between academic preparation and industrial demands (Shen Y.H. & Yang Y.D., 2024). In response, contextualized and comprehensive engineering courses that integrate knowledge from various subfields—such as design, physics, and engineering specialties—have emerged as key to reform. Notable examples include the integrated STEM courses in Arizona State University’s Mars Education Project (Yang Y.J. & Rao F.F., 2019), Jilin University’s “Four-Span” Bionic Machinery Design course (Niu S.C. et al., 2024), and the curriculum cluster-based postgraduate program in vehicle engineering at the University of Science and Technology Beijing (Shen Y.H. & Yang Y.D., 2024).

Accordingly, this paper adopts the second perspective, defining general engineering courses for professional engineering graduate students as an extension and broadening of specialized education. These courses aim to equip students with the skills to engage with complex engineering systems and solve real-world problems through contextualized, interdisciplinary learning.

***Theory of Authentic Learning***

The theory of authentic learning, rooted in constructivist epistemology, posits that thinking and learning acquire meaning only when situated within specific, real-world contexts. According to this view, learning activities must be closely connected to real-life scenarios in order for students to develop a deep understanding of core concepts and their underlying value. Authentic learning typically features several structural characteristics, including authentic context, authentic tasks, authentic outcomes, authentic identity, and authentic value (Sasha A. et al., 2000; Strobel et al., 2013). These elements serve as a vital bridge between abstract engineering knowledge and its practical application in real-world professional environments—a process often referred to as "Bridging Apprenticeships." This concept emphasizes the organic interplay among learning activities, workplace practices, and broader social contexts (Resnick, 2013; Billett, 1994). Jan Herrington (2007) further distilled these principles into a set of design elements for authentic learning environments, which have since provided a theoretical foundation for a wide body of related research. These elements are summarized in Table 1.

**Table 1 Design Elements of Authentic Learning Proposed by Jan Herrington (2007)**

| Elements | Connotations |
| --- | --- |
| Authentic Context | Present a complete and realistic environment to demonstrate how knowledge is practically applied. |
| Authentic Activities | Students need to discover and solve real, ill-structured engineering problems. |
| Imitating Expert Work Performance | Provide opportunities to access expert thinking and performance, enabling students to observe expert performance and simulate activity processes before attempting. |

| | |
|---|---|
| Multiple Roles and Perspectives | Provide opportunities to access and investigate multiple viewpoints, roles, and perspectives. |
| Reflection | Require students to reflect based on extensive knowledge to make predictions, hypotheses, and experiments, generate solutions and solve problems. |
| Cooperation | Provide opportunities to solve problems in the form of group cooperation. |
| Expression | Provide opportunities for self-expression, including forms such as group discussions, presentations, interviews, and debates. |
| Tutoring and Scaffolding | The role of teachers changes from traditional lecturing to providing resources, reminders, feedback, and guidance when necessary. |
| Authentic Evaluation | The evaluation of students is based on the learning process rather than a single test, such as portfolios, learning logs, self-assessments, etc. |

### *Authentic Characteristics of General Engineering Courses*

The literature review indicates that general engineering courses aim to engage students in authentic, project-based learning that encourages the active integration of multidisciplinary knowledge and skills, thereby fostering a range of comprehensive competencies, including interdisciplinary thinking in real-world contexts (Chen X. M., 2006). Based on this understanding, we argue that authenticity constitutes the core characteristic of general engineering courses, which is embodied in the following five dimensions: **(a)Authentic Context:** The learning environments created in such courses closely resemble real-world professional settings or work scenarios that students are likely to encounter in their future careers. **(b)Authentic Process:** Students engage with the full spectrum of industrial processes, encompassing key phases such as engineering design, production management, quality control, and market analysis, thereby gaining holistic exposure to real engineering workflows. **(c)Authentic Task:** The learning activities, including both the content and procedures, mirror genuine engineering practices, enabling students to simulate real-life problem-solving processes. **(d)Authentic Cooperation:** Students become part of real or simulated engineering practice communities, where they participate in collaborative projects and experience teamwork and interpersonal dynamics characteristic of professional industrial environments. **(e)Authentic Evaluation:** These courses emphasize the practical value of learning outcomes for individuals, teams, and broader communities, assessing not only academic performance but also the real-world impact of students' work (Strobel J. et al., 2013).

## THE 5AX DESIGN MODEL OF GENERAL ENGINEERING COURSES

The authentic characteristics of general engineering courses cannot be fully realized through a single lesson but require a series of interconnected activities. Consequently, the design of these courses must incorporate the nine key elements: authentic context, authentic activities, imitation of expert work performance, multiple roles and perspectives, reflection, cooperation, expression, tutoring and scaffolding, and authentic evaluation. These elements should be used to structure coherent and organized learning sequences. Based on the five authentic characteristics outlined earlier, this paper organizes the learning activities into five key stages:

a. Activities of Adapting to Authentic Engineering Scenarios (Authentic Scenario, AS)

b. Activities of Experiencing Complete Industrial Processes (Authentic Process, AP)

c. Activities of Completing Authentic Engineering Tasks (Authentic Tasks, AT)

d. Activities of Conducting Authentic Engineering Collaborations (Authentic Collaboration, AC)

e. Activities of Evaluating Authentic Engineering Values (Authentic Evaluation, AE)

These five stages are encapsulated in the 5AX model of general engineering courses, as illustrated in Figure 1. Specifically, AS serves as the introductory phase, AP and AT represent the core practice stages, AC is a critical component throughout the process, and AE provides the overall evaluation of the learning activities.

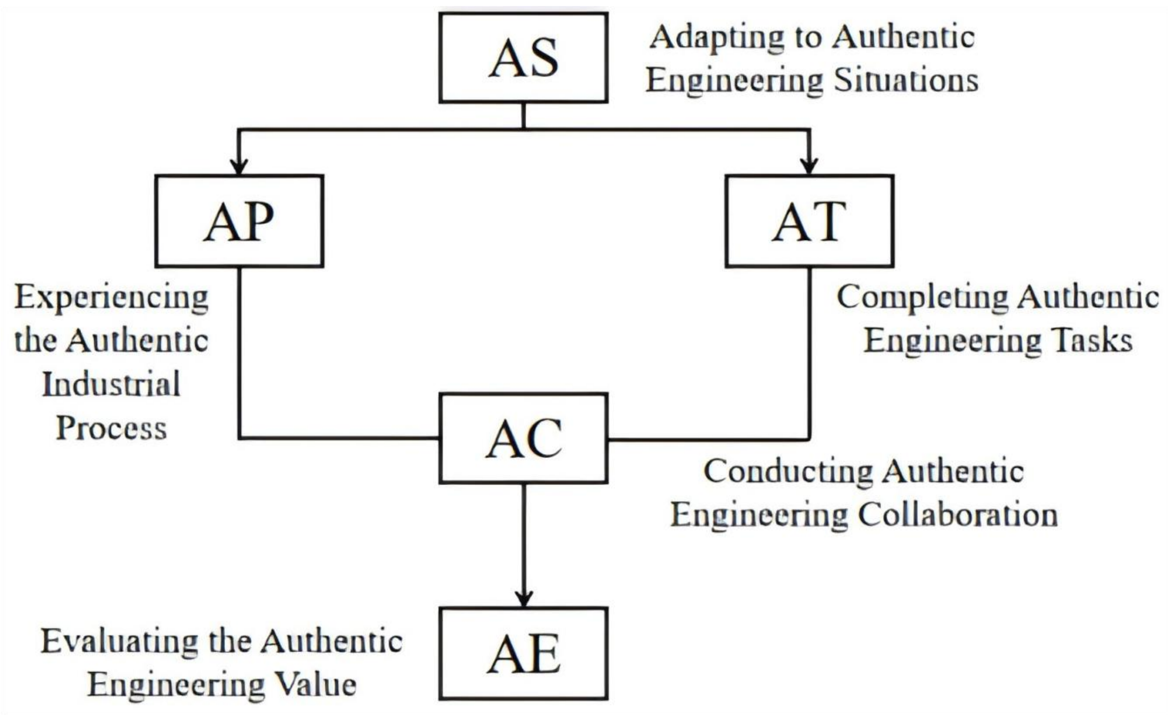


**Figure 1. The 5AX Design Model for General Engineering Courses**

***Activity 1: AS, namely the Activity of Adapting to Authentic Engineering Situations***

This activity aims to immerse students in authentic problem situations, where the learning environment closely mirrors real-world working environments or professional contexts that students are likely to encounter in their future careers (Herrington A and Herrington J, 2008). It encompasses three key aspects of authenticity: personal, social, and physical.

a. The authenticity of the personal scenario allows students to take control of their learning process, gain hands-on experience, and directly apply theoretical knowledge to real-world situations. This scenario integrates daily experiences, students' interests, and professional aspirations into the learning process.

b. The authenticity of the social scenario reflects the complexities and interpersonal interactions students will face in real-world challenges. It emphasizes solving open-ended, interdisciplinary problems, thus mirroring the social dynamics of professional environments.

c. The authenticity of the physical scenario ensures that students have access to professional equipment and tools used in actual engineering projects, as well as ample space for practical activities.

By introducing real engineering scenarios into the curriculum, an interdisciplinary learning space can be created, enabling students to connect diverse fields of knowledge to real-world applications. To achieve this, several strategies can be employed, such as allowing students to choose learning topics based on their personal experiences or interests, incorporating real-world case studies into classroom discussions, or teaching the curriculum at actual engineering sites or practice platforms.

***Activity 2: AP, namely the Activity of Experiencing the Authentic Industrial Process***

The core of this activity is to provide students with a comprehensive experience of the complexity and reality of industrial processes, allowing them to simulate or actively participate in various stages such as engineering design, production management, quality control, and market analysis. Engineering projects extend beyond technical execution; they encompass the entire life cycle, from conceptual design to the delivery of finished products. Engaging in these stages enables students to gain insight into the full process of transforming a product from an initial concept to its final realization. By participating in real engineering projects or simulating industrial processes—using tools like virtual reality technology or computer-aided design systems—students can experience firsthand the challenges of real-world scenarios and make critical decisions. Through this activity, students not only acquire interdisciplinary knowledge but also develop a deeper understanding of engineering design logic, the complexity of process collaboration, and how market demands influence technological choices. Furthermore, the role-playing and task division emphasized in the activity help students cultivate the ability to integrate multidisciplinary knowledge. This includes analyzing problems from various perspectives, such as management, economics, and technology. As a result, students improve their practical skills and recognize that engineering projects are not solely technical endeavors but also require consideration of economic factors, environmental sustainability, and social responsibilities (Sasha A et al., 2000).

***Activity 3: AT, namely the Activity of Completing Authentic Engineering Tasks***

When designing general courses for engineering majors, adopting a project-based learning approach is essential to engage students in the activity of completing real engineering tasks. This approach involves students independently selecting and solving unstructured, open-ended engineering problems that do not have fixed solutions. To tackle such complex issues, students must apply the interdisciplinary knowledge and skills they have acquired, integrating them with the real-world context to design a reasonable solution. To address these challenging projects effectively, students must conduct multi-dimensional analyses and adapt flexibly to changing conditions. For instance, when working on a project related to new energy vehicles, students need to draw upon knowledge from various fields such as new energy, mechanical engineering, and artificial intelligence. They must also balance factors like technical feasibility, economic cost, and environmental impact when making decisions. By completing such tasks, students not only apply interdisciplinary knowledge but also develop systematic thinking and innovative problem-solving abilities in the context of real engineering challenges. Moreover, the final task outcomes are evaluated according to real-world criteria, providing students with a deeper understanding of the feasibility and impact of the solutions they propose in practical scenarios.

***Activity 4: AC, namely the Activity of Conducting Authentic Engineering Collaboration***

The actual working environment in engineering disciplines often requires teamwork, particularly when addressing complex, interdisciplinary problems. Therefore, conducting real engineering collaboration activities is not only a way to assess students' academic abilities but also a means to develop their teamwork, communication, and decision-making skills. Curriculum design can be approached from three key aspects.

First, the role of the teacher should be transformed. Teachers no longer function as traditional lecturers but as supporters and guides, offering "scaffolding" assistance. During the project selection and implementation phases, teachers provide resources, establish the task framework, and offer timely reminders and feedback when students encounter difficulties. This supportive approach encourages students to solve problems independently while acquiring interdisciplinary knowledge through exploration and collaboration.

Second, teamwork should be at the core of the activity. Students are divided into groups and assigned different roles based on their disciplinary backgrounds and expertise. They must collaborate effectively by communicating, sharing information, coordinating tasks, and resolving conflicts. This cooperative process not only sharpens students' sense of teamwork but also allows them to experience firsthand the integration of interdisciplinary knowledge.

Third, opportunities should be provided for students to engage with professional practice communities and collaborate with actual stakeholders such as industry experts, company representatives, and community members. Through these collaborations, students can receive external feedback, incorporate real-world needs into their projects, and enhance the realism and practicality of their work. This step not only tests students' interdisciplinary learning in real-world contexts but also cultivates their ability to cooperate with external partners, ensuring that learning is integrated with genuine engineering practice.

***Activity 5: AE, namely the Activity of Evaluating the Authentic Engineering Value***

The evaluation phase serves not only as an assessment of the project's outcomes but also as a comprehensive review and reflection on the knowledge and skills that students have acquired throughout the project. In this phase, students' engineering projects should be evaluated not only from a technical perspective but also from multidimensional viewpoints, including economic, social, and environmental factors, allowing students to understand the broader value of engineering work. For instance, in addition to assessing the technological innovation of the project, it is crucial to evaluate its performance in terms of economic feasibility, social impact, and environmental sustainability. Such a comprehensive evaluation enables students to appreciate that engineering is not solely focused on technology, but also serves societal needs and contributes to human well-being.

Furthermore, through team-based evaluations and self-reflections, such as portfolios and learning logs, students can assess their individual contributions and reflect on how they can enhance their skills for future engineering endeavors. This reflective process helps students build confidence in their professional abilities, providing a clearer understanding of their future career development and fostering a sense of assurance in their vocational path. Additionally, the evaluation can be enriched by input from interdisciplinary tutor groups or feedback from industry experts, giving students a more comprehensive understanding of the evaluation criteria and standards in real-world engineering contexts. This process not only promotes students’ technical and interpersonal growth but also aligns their learning outcomes with industry expectations.

## THE PRACTICE OF GENERAL ENGINEERING COURSES BASED ON THE 5AX MODEL

***Course Background***

In 2016, Zhejiang University established the Zhejiang University Engineer School (Zhejiang Engineer School), which integrates high-quality educational resources from various departments across the university, including science, engineering, economics, management, and medicine. This integration has led to the formation of a new model for cultivating exceptional engineering talent, characterized by "substantive operation, project-based organization, all-around training, and full-chain collaboration." As part of this initiative, the Engineering Innovation and Training Center (hereinafter referred to as the Training Center) was established to support these educational goals.

The Training Center consolidates eight training platforms, including electrical technology and equipment, robotics and intelligent manufacturing, and information and microelectronics technology, as well as several specialized laboratories, such as the Key Laboratory of Cooperative Sensing and Autonomous Unmanned Systems of Zhejiang Province. Additionally, the center collaborates with enterprise training bases, including those from major corporations like PetroChina, which serve as teaching and practice hubs for postgraduate students, further enhancing their practical learning experience.

***Course Overview***

To effectively meet the goals and requirements for cultivating outstanding engineers, the Zhejiang University Engineer School, in collaboration with the Training Center, has developed the course "Advanced Engineering Cognition and Practice" for professional master's degree postgraduate students. This course is designed as a foundational, experimental, and practical training course for professional master's degree students in engineering, and it also serves as an elective labor-education course for students across other disciplines or academic levels within the university. Since its inception in 2022, the course has been offered annually to over 500 professional master's degree postgraduate students.

The course has two primary objectives. First, it aims to enhance engineering awareness and cultivate comprehensive skills. Through a modular teaching approach that integrates theory, virtual reality, and hands-on experience, students gain a thorough understanding of basic engineering processes such as design, manufacturing, testing, and analysis. The course also focuses on building the toolchain, knowledge chain, and resource chain necessary for engineering innovation, while strengthening students' engineering awareness related to quality, efficiency, standards, environmental protection, and safety.

Second, the course seeks to promote system concepts and deepen students' industrial understanding. By engaging in comprehensive engineering innovation system development practices, students are encouraged to develop a holistic understanding of complex engineering systems and interdisciplinary fields. The course also equips students with fundamental methods of system integration, collaborative management, and innovative development, while fostering their ability to apply interdisciplinary knowledge in solving real-world problems through systematic thinking and engineering innovation.

***Course Content***

The course "Advanced Engineering Cognition and Practice" comprises a total of 69 class hours and is worth 3 credits. It is structured into two main stages: the compulsory study of 8 modules and 1 system study, as illustrated in Figure 2.

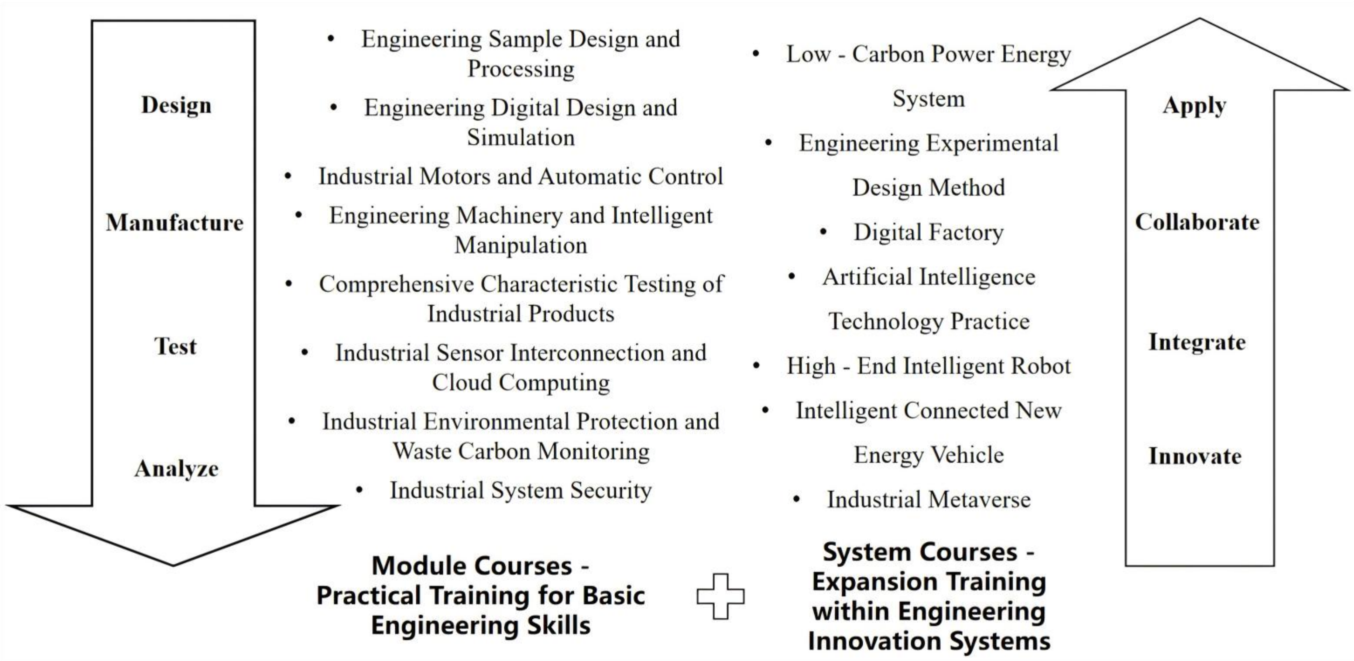


**Figure 2. "8 + X" Course Structure of "Advanced Engineering Cognition and Practice"**

In the first "module course" stage, the course provides experimental training across eight foundational modules, including engineering digital design and simulation, engineering sample design and manufacturing, engineering machinery and intelligent control, engineering motors and drive control, comprehensive characteristic testing of industrial products, industrial environmental protection and waste carbon monitoring, industrial sensor interconnection and cloud computing, and industrial system security. This stage enables students to gain a thorough understanding of core processes such as engineering design, manufacturing, testing, and analysis. It helps them build the toolchain, knowledge chain, and resource chain essential for engineering innovation, while also developing critical engineering skills related to quality, efficiency, environmental protection, and safety.

In the second "system course" stage, students select one of seven modules based on their personal interests and future career directions. These modules include low-carbon power energy systems, high-end intelligent robots, intelligent network-connected new energy vehicles, industrial metaverse, engineering experimental design methods, digital factories, and artificial intelligence technology practice. Through this stage, students engage in engineering innovation system development, familiarize themselves with system integration, collaborative management, and innovative applications, and enhance their systematic thinking and problem-solving abilities using interdisciplinary knowledge.

***Course Characteristics***

Based on the 5AX design model and data from course construction and interviews, this paper identifies four core characteristics of the course "Advanced Engineering Cognition and Practice":

Firstly, the course constructs diverse scenarios to facilitate authentic learning. The "Advanced Engineering Cognition and Practice" course integrates three distinct scenarios for authentic engineering learning: teaching tasks, virtual simulations, and industrial sites. The teaching task scenario involves creating real and meaningful engineering practice problems in the classroom, primarily for knowledge transfer. These tasks present students with contextualized engineering cases that are intentionally "conceptually unclear and ill-structured," encouraging critical thinking and problem-solving. In the modular courses, the interdisciplinary engineering expertise of instructors is emphasized, with engineering problems framed within specific scenarios. The use of modern tools, such as computing devices and digital scanners, enhances the teaching process. The virtual simulation scenario employs modern digital technologies to simulate engineering laboratories online or dynamically showcase industrial sites, offering students highly realistic, visual, and interactive learning content that mirrors actual engineering processes. Platforms such as the Quzhou Chemical Training Platform and the AR/VR virtual training on the Ultra-Visual Training Platform at the Science and Innovation Center further immerse students in simulated real-world environments. This simulation enhances students' understanding of engineering sites, fostering a sense of presence, immersion, and interactivity that bridges theoretical knowledge and engineering practice. The industrial site scenario involves hands-on engineering practice at training platforms provided by universities, enterprises, or joint university-enterprise initiatives. These platforms offer real equipment, production lines, and R&D projects, allowing students to engage as "apprentices," "interns in full-time positions," or "student engineers." Here, students complete engineering designs or production processes, contributing to actual projects. In the system courses, project topics are drawn directly from real problems presented by enterprises, and students work on these projects at the Engineer Training Center or enterprise bases, receiving guidance from both industrial experts and university professors.

Secondly, the course integrates the entire industrial process into its construction. In "Advanced Engineering Cognition and Practice," the basic engineering skills training courses, or modular courses, incorporate the four essential stages: design, manufacturing, testing, and analysis. In the engineering innovation system expansion training courses, known as the system courses, the additional stages of innovation, integration, collaboration, and application are integrated, thus effectively covering the full industrial process. This comprehensive approach allows students to apply interdisciplinary knowledge from fields such as machinery, the Internet, and materials science at various stages. For instance, in the manufacturing and testing stages, students are tasked with solving practical problems that require them to synthesize interdisciplinary knowledge, fostering their ability to tackle complex challenges. Moreover, the system courses progressively emphasize innovation, integration, collaboration, and application through real-world projects and teamwork, providing students with hands-on experience. This not only enhances their understanding of the full industrial process but also nurtures professional qualities and a sense of social responsibility, which are essential for future engineering practices. As a result, students develop a stronger identification with their engineering role and mission, reinforcing their professional engineering identity.

Thirdly, the course enhances the flexibility of accessing interdisciplinary resources. In "Advanced Engineering Cognition and Practice," the Engineer School has established a school-enterprise mentor group composed of experts and scholars from various industries. This group provides students with the opportunity to interact closely with industry professionals, offering guidance on real-world projects and feedback on emerging industry trends. This collaborative relationship helps students bridge theory and practice, strengthening their ability to solve interdisciplinary problems independently. Additionally, the course design allows students to select system courses based on their personal interests and career development goals. Through consultation with the mentor group, students can choose real projects to work on and receive tailored resources and guidance. This flexible approach not only fosters students' enthusiasm for learning but also encourages them to delve deeper into their areas of interest, ultimately helping them develop unique strengths and career paths. Together, these features promote the holistic development of students within an interdisciplinary context, providing a solid foundation for their future professional careers.

Fourthly, the course adopts an assessment approach that emphasizes group collaboration and the practical value of projects. The "Advanced Engineering Cognition and Practice" course utilizes a project-based learning and evaluation mechanism. For example, in the "Engineering Sample Design and Processing Results" module, the evaluation consists of a report (70%), attendance (10%), and a design model (20%). The significant weight given to the group report highlights the course's focus on students' communication skills, teamwork, and ability to present their findings effectively. Furthermore, the course assessment places a strong emphasis on the real-world relevance of projects. In the system courses, the selection of project topics is determined through consultations between students and the mentor group. During the final assessment, the presentation and evaluation of the results involve input from industry experts. Students are required to present their design concepts, research findings, and plans for future applications. Exceptional projects may even have the opportunity to continue collaborating with industry partners in the future.

*Course Outcomes*

This study conducted in-depth interviews with 11 students who were either currently enrolled in or had previously completed the "Advanced Engineering Cognition and Practice" course, focusing on their learning experiences and outcomes. The total duration of the interviews was 136 minutes, and excerpts from the interviews are presented in Table 2. Analysis of the interview content revealed that students generally had a positive experience with the course. They reported gaining interdisciplinary knowledge and felt that the course significantly enhanced their abilities in teamwork, systematic thinking, engineering practice, and their understanding of the engineering industry (Joachim W. et al., 2011).

**Table 2. Contents of Student Interviews**

| Number | Interview Statement | Course Outcomes |
| --- | --- | --- |
| 1 | An engineer should have a wide range of knowledge. This course selects eight modules by utilizing the resources of the existing Engineer School, which has broadened my knowledge scope. | Interdisciplinary Knowledge |
| 2 | Through this course, we have not only learned the operation methods of tools like robotic arms, but also grasped the underlying thinking and design methods of these tools. | Systematic Thinking |
| 3 | The course didn't adopt the traditional lecture-based teaching method but focused on "teaching + practice". | Engineering Practical Ability |
| 4 | Enterprises were deeply involved in the course teaching, and we have got many opportunities for enterprise internships. Engineering Practical Ability, | Understanding of the Engineering Industry |
| 5 | There will be reminders in the software, for example: "You are operating remote physical facilities. Please confirm whether the surrounding environment is safe or not." | Engineering Practical Ability |
| 6 | The course covers too many directions, which are different from my major, and it requires a lot of our time and energy. | Interdisciplinary Knowledge |
| 7 | I think it was interesting that we were asked to operate robotic dogs in the robotics class. The teacher only taught the basic usage methods, provided operation manuals, and gave guidance when necessary. We carried out independent exploration in groups, learned laser positioning and mapping, and finally presented our projects. Teamwork Ability, | Systematic Thinking Ability |
| 8 | We can use the Shining 3D CAD software provided by | Engineering Practical |

| | |
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| enterprises for free, and the laboratory also provides us with digital scanners, 3D printers, etc. | Ability |

**DISSCUSION**

The core objective of this study is to explore the essential characteristics of general engineering courses for postgraduate students pursuing professional engineering degrees and to develop a course design model that embodies these characteristics. Firstly, through a comprehensive literature review, we analyzed the positioning and functions of general engineering courses, which aim to extend and deepen engineering professional education. These courses are designed to cultivate graduate students' interdisciplinary knowledge and their ability to solve complex engineering problems within contextualized learning environments. Additionally, based on authenticity learning theory, we identified that the core characteristic of general engineering courses is authenticity, which manifests in five dimensions: authentic scenarios, authentic processes, authentic tasks, authentic collaborations, and authentic evaluations. Secondly, we proposed the 5AX design model for general engineering courses. In this model, students first adapt to the Authentic Scenario (AS) activity during the initial introduction stage. In the specific practice stage, students engage in the Authentic Process (AP) activity, complete the Authentic Tasks (AT) activity, and participate in Authentic Collaboration (AC) activities simultaneously. In the final evaluation stage, students are required to assess the Authentic Evaluation (AE) activity. The model consists of three interlocking stages and defines nine key elements—authentic scenarios, authentic activities, imitation of expert work performance, multiple roles and perspectives, reflection, cooperation, expression, tutoring and scaffolding, and authentic evaluation. This framework aims to guide the development of general engineering courses, enhancing the authenticity of learning activities and, consequently, improving students' learning outcomes. The introduction of the 5AX model represents a significant theoretical contribution of this paper, integrating authenticity learning theory with general engineering education, and provides a potential direction for future research.

Through interviews with learners of the case courses in this study, it was found that students generally had positive evaluations of the courses, believing that they had gained interdisciplinary knowledge and effectively enhanced their teamwork skills, systematic thinking, engineering practice capabilities, and understanding of the engineering industry. In this section, we aim to analyze the talent cultivation mechanism of engineering general courses characterized by authenticity (Lee Y. Y. R. et al., 2020). First, the course uses scenario reconstruction as a key link. The introduction of holistic and dynamic situations allows individuals to approach "real problems" from a comprehensive perspective, develop transferable skills, and trigger "real cognition." In authentic learning, core knowledge, essential abilities, and creative thinking are deeply embedded in real-life situations, continuously becoming richer and more refined as the situations evolve. Second, the course employs project practice as the mechanism. Authentic learning centers around "real projects," which serve as the main thread for the generation and development of individual knowledge. This transforms situational knowledge from a scattered and disorganized set of information into a cohesive system with logical and metaphorical relationships. "Project practice" helps students integrate fragmented knowledge and methods from multiple dimensions into their own cognitive framework, thus fostering their creative thinking and transferable abilities. Third, the course pursues cognitive authenticity as its goal. Authentic learning enables students to exchange knowledge and share skills with diverse groups, allowing them to impart empirical meaning to their knowledge during the exploration process. This process helps reconstruct their cognitive structures, strengthens their identification with their role as engineers, and better equips them to adapt to real and complex engineering systems. In conclusion, this study has preliminarily explored the talent cultivation outcomes and mechanisms of authentic engineering general courses. However, since only one case was qualitatively analyzed, there is insufficient theoretical saturation and a lack of empirical validation. Future studies will expand the number of cases and incorporate quantitative research methods.

## CONCLUSIONS

This paper explores the positioning and authenticity characteristics of general engineering courses, identifying five key dimensions of authenticity: authentic scenarios, authentic processes, authentic tasks, authentic collaborations, and authentic evaluations. In response to these characteristics, the paper proposes the 5AX design model, which includes activities such as adapting to real engineering scenarios, experiencing complete industrial processes, completing real engineering tasks, conducting real engineering collaborations, and evaluating the real value of engineering outcomes. This model offers specific guidance for constructing general engineering courses.

Furthermore, the paper examines how the "Advanced Engineering Cognition and Practice" graduate course at Zhejiang University Engineer School applies the 5AX model. The course is found to have four distinct characteristics: constructing diverse scenarios for authentic learning, integrating the complete industrial process into course design, enhancing flexibility in accessing interdisciplinary resources, and adopting an assessment form that emphasizes group cooperation and the real value of projects. This case study illustrates a high degree of authenticity and effectively nurtures graduate students' systematic thinking, teamwork skills, and ability to address complex engineering problems.

In conclusion, the paper highlights that the construction of general engineering courses should integrate resources from various colleges, strengthen industry-university collaborations, engage enterprises more actively, and incorporate industry mentor guidance, the latest industry trends, and real-world scenarios. These efforts will deepen graduate students' understanding of the industry and reinforce their systematic thinking.

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