Exploring and Implementing a New Model of Engineering Experimental Teaching in Universities from the Perspective of Industry-Academic Integration

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Abstract: This article explores the current state of engineering experimental teaching in universities and proposes a novel model through the lens of industry-academic integration. Through a comprehensive examination of current practices, it identifies challenges related to curricula, resource allocation, and teaching methodologies that impede the improvement of teaching quality and the development of students' practical skills. To address these challenges, this article introduces a student-centered and industry-aligned model of engineering experimental teaching. This model integrates various teaching elements, refines teaching techniques, and enhances the learning environment, all with the goal of nurturing students' practical abilities and promoting innovation. Through rigorous case studies, the article demonstrates the effectiveness of this model in enhancing the quality of engineering experimental teaching. The findings reveal significant improvements in students' experimental learning outcomes, an enhancement in their practical proficiencies, and a subsequent increase in graduate employment rates, earning recognition from corporate and societal stakeholders. This proven success provides a valuable roadmap for other institutions aiming to revitalize their engineering experimental teaching practices.

1. Introduction

The integration of industry and education represents a collaborative and interconnected partnership aimed at enhancing students' practical skills and aligning them with the evolving demands of industrial progress [1]. As the economy and society rapidly advance, this integration has become a crucial element of tertiary education reform [2]. In the context of engineering experimental teaching in universities, this fusion holds significant importance. Historically, engineering experimental teaching has prioritized theoretical knowledge over practical skills [3]. However, with societal advancements and industrial transformations, a mere theoretical understanding is no longer sufficient to meet the demands of society [4]. Consequently, universities must establish stronger connections with industries in their engineering experimental teaching, closely aligning it with industrial trends to enhance students' practical expertise and adaptability to industrial requirements [5].

Exploration of innovative models of engineering experimental teaching for fostering students' practical abilities and alignment with industrial needs holds profound significance, both practically and theoretically [6]. Given the increasing employment challenges faced by engineering majors amidst societal and industrial shifts [7], enhancing students' practical proficiencies and industry alignment is crucial for their successful entry into the workforce and future career prospects. Moreover, the traditional engineering experimental teaching paradigm, now outdated and inadequate for contemporary needs, requires urgent reform and reinvention [8]. By delving into these new teaching models, valuable insights and guidance can be obtained to revitalize and advance engineering experimental teaching practices in universities.

2. Educational ideas and instructional theories supporting the new model

The development of the new model is intrinsically connected to the implementation of cutting-edge educational ideologies and teaching frameworks. At the core of this model lies a student-focused

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approach, emphasizing the crucial role of learners in shaping their own educational journey. Teachers are responsible for tailoring their curricula and methodologies to align with the unique needs and characteristics of students, thereby igniting their passion for academic pursuits. The competency-based teaching framework serves as a fundamental pillar of this innovative model [9], highlighting the significance of nurturing skills and applying theoretical knowledge to real-world contexts. Contemporary teaching strategies, such as collaborative learning and inquiry-based instruction, also provide valuable insights for the design of this model. These methods prioritize learner interaction, cooperation, and the cultivation of both innovative and critical thinking abilities.

3. Analysis of the current situation of engineering experimental teaching in universities

With the continued advancement of tertiary education, engineering experimental teaching has gained increasing attention within universities as a crucial avenue for nurturing students' hands-on skills and innovative mindset. However, practical implementation has revealed various obstacles that hinder its progress. This discussion delves into the current landscape of engineering experimental teaching in higher education institutions.

(1) Curriculum design for experimental teaching

Currently, university engineering experimental teaching curricula exhibit a diverse range of approaches [10]. Some institutions offer it as a standalone course, focusing on the development of practical skills. Others integrate it with theoretical instruction, using experiments to validate and reinforce conceptual knowledge. Additionally, certain universities tailor experimental courses to specific majors, incorporating their unique characteristics. Yet, challenges persist: inadequate course scheduling limits students' practical exposure; experimental content often fails to align with real-world demands, lacking relevance and innovation; and a lack of curriculum cohesion and structure prevents the formation of a comprehensive experimental teaching framework.

(2) Resources and environment for experimental teaching

The allocation and utilization of resources and environments for experimental teaching are crucial benchmarks for assessing the quality of engineering experimental education in universities. Currently, some institutions face inadequate investments in this area, leading to issues such as outdated laboratories and equipment. These deficiencies not only hinder teaching progress but also undermine students' ability to develop practical and innovative skills. Furthermore, problems exist in resource utilization: limited laboratory hours at some universities fail to accommodate students' experimental needs, while inefficient equipment usage at others results in resource wastage.

(3) Instructional methods and tools for experimental teaching

The prevailing instructional methods employed in engineering experimental teaching primarily consist of traditional lecturing, case studies, and simulation experiments. While these approaches can aid in theoretical understanding and enhance practical skills to some extent, they also have notable drawbacks. Traditional lecturing, although systematic in delivering knowledge, often leaves students in a passive learning mode, lacking engagement and creativity. Case studies, while helpful in understanding real-world problem-solving, often suffer from a lack of timely updates, rendering their analyses outdated and irrelevant. Simulation experiments, despite offering a controlled environment for practice, often fall short in terms of authenticity and complexity, failing to fully replicate actual conditions.

Hence, there is significant room for improvement in the prevalent experimental teaching techniques. Universities should proactively explore innovative experimental teaching approaches and strategies, such as incorporating project-oriented learning, flipped classrooms, and embracing other educational paradigms to stimulate students' academic interest and enthusiasm. Simultaneously, careful attention must be given to managing the processes and assessing the outcomes of experimental instruction to ensure its quality and impact.

4. Construction of a new model of engineering experimental teaching from the perspective of industry-academic integration

In the context of integrating production and education, there is an urgent necessity for engineering experimental instruction to develop a cutting-edge pedagogical model. This model should align more closely with industry requirements and enhance students' hands-on skills. We will delve into the creation of this model across three dimensions: design philosophy, structural outline and content, and implementation tactics.

(1) The design philosophy of the new paradigm: Prioritizing a student-focused and industry-aligned approach.

The development of this novel model must revolve around the learner, taking into account their unique needs and attributes. Unlike traditional experimental teaching, which often revolves around the instructor and leads to a passive learning experience and subpar outcomes, this new approach should elevate students to the forefront. It should prioritize igniting their curiosity and drive for learning, enabling them to actively engage, experiment, and innovate within the practical setting. Furthermore, this model must maintain a close alignment with industry trends and market demands. To achieve this, universities should foster collaborative relationships with industry partners, jointly crafting experimental curricula, developing resources, and designing projects. This ensures that experimental instruction remains relevant and responsive to real-world demands. Additionally, universities should proactively incorporate cutting-edge technologies and management practices from the industry, continually elevating the standard and quality of their experimental offerings.

(2) The structure and substance of the revamped model: Delving into the intricacies of the model's constituent elements.

The architecture of this refreshed approach primarily encompasses learning outcomes, curricular content, and teaching methodologies, among other essential components.

Regarding learning outcomes, the revamped model prioritizes the cultivation of students' hands-on skills, inventive mindset, and professional attainment. Tailored and quantifiable experimental learning objectives are outlined, taking into account the distinct attributes of various disciplines and the needs of learners.

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Concerning teaching methodologies, the revamped model incorporates a plethora of engaging techniques, such as project-based learning, flipped classrooms, and case studies. This diversity aims to pique students' interest and passion for learning. Furthermore, meticulous attention is paid to the management of the experimental learning process and the assessment of its outcomes, thereby guaranteeing the quality and impact of the experimental education.

(3) Implementation strategy of the new model: Putting forward specific implementation steps and strategies.

To ensure the seamless implementation of the new model and achieve desired outcomes, the following tailored steps and strategies are proposed:

Universities ought to bolster their investment and support for practical education, enhancing the facilities and environments conducive to experiential learning. This provides a robust foundation for the progress of hands-on teaching. Simultaneously, emphasis should be placed on bolstering the capabilities of practical education instructors, elevating their skills and proficiency.

Universities must proactively facilitate the evolution of teachers' roles, shifting them from traditional disseminators of knowledge to mentors and facilitators of practical learning. Instructors should strive to engage students, fostering active participation in experimental endeavors and nurturing a spirit of inquiry and innovation.

A focus on student engagement is paramount, encouraging active involvement throughout the experimental learning journey. Mechanisms such as reward systems and skills competitions can be leveraged to ignite students' passion for practical work. Furthermore, rigorous assessment and feedback processes should be established to ensure timely identification and resolution of any challenges encountered, continually optimizing the impact of practical instruction.

5. Case study on the new model of engineering experimental teaching

5.1. Case selection and analysis

This study examines the implementation of an innovative engineering experimental teaching model at Guangdong University of Technology. Over the past few years, the institution has been at the forefront of blending educational and industrial practices, collaborating closely with various enterprises to co-create an engaging engineering experimental curriculum. This case study focuses on students majoring in Mechanical Engineering who took the course 'Robotics'. By adopting a student-centered and industry-aligned approach, the university has notably excelled in fostering students' hands-on skills and creativity from 2021-2023.

This specific course aimed to provide students with theoretical knowledge and practical skills in the field of robotics. The study analyzed the students' learning outcomes, their engagement in hands-on activities, and their overall performance in the course. Through various assessment methods, including exams, projects, and practical demonstrations, the researchers evaluated the effectiveness of the course in enhancing students' understanding of robotics concepts and their ability to apply them in real-world scenarios. The findings from this case study provided valuable insights into the impact of the 'Robotics' course on students' learning experiences and skill development in the field of Mechanical Engineering. Initially, rich qualitative insights were gathered through interviews and observations, shedding light on the new engineering experimental teaching paradigm, student feedback, and faculty assessments. Complementing this, quantitative metrics such as recent experimental teaching outcomes and student employment rates were collected to assess the effectiveness of the model. A detailed breakdown of students' experimental teaching performance is presented in Table 1.

Table 1 Comparison of students' experimental teaching results

School year	Average score (Out of 100)	Top score (Out of 100)	Lowest points (Out of 100)	Number of students in the class	Achievement of course objectives
2021 (before implementation)	78.7	94.4	45.2	75	67%
2022 (after implementation)	80.4	98	61	59	70.1%
2023 (after implementation)	91.1	100	61	60	84.2%

Student employment rate for example, Table 2:

Table 2 Comparison of student employment rate

Graduation year	Student satisfaction (Out of 5)	Employment rate	Number of cooperative enterprises in employment
2021 (before implementation)	4.4	88.6%	2
2022 (after implementation)	4.62	91%	7
2023 (after implementation)	4.75	96.8%	15

Evaluation of influencing factors is shown in Table 3:

Table 3 Evaluation of influencing factors

Influencing factor	Evaluate
Hands-on engineering experiments	Very important
School leaders attach great importance to and strongly support them.	Somehow important
The active participation and selfless dedication of teachers' team	Moderately important
Deep participation and resource sharing of business circles	Very important
Students' active participation and exploration	Very important

After analysis, it has been determined that the implementation effect of the new model of engineering experimental teaching in this university is remarkably impressive, as shown in Table 1 and 2. Firstly, students' practical abilities and innovative spirits have been effectively enhanced, as evidenced by their significant improvement in score results. Additionally, students have achieved excellent outcomes in various practical activities and competitions. Secondly, the university's student satisfaction and graduate employment rate have continued to rise, garnering widespread recognition from both enterprises and society.

Regarding the influencing factors, this article identifies several key factors contributing to the success of the new model of engineering experimental teaching in this university. Firstly, Hands-on engineering experiments have played a crucial role. Secondly, the support of school leaders and teaching team have been instrumental in the implementation. Thirdly, the deep involvement and resource sharing from the business community have proven beneficial. Lastly, the active participation and exploration by the students themselves have also significantly contributed to the success of the model.

5.2. Case summary and enlightenment

Through the examination of the practical application of the innovative engineering experimental teaching model at this university, several key insights emerge:

Firstly, institutions need to prioritize the establishment and implementation of this new teaching paradigm. It should be seamlessly integrated into the overall institutional development strategy, with adequate resources allocated to ensure its success.

Secondly, to align experimental teaching with real-world demands, universities must foster stronger collaborations with industries. This involves jointly shaping the experimental curriculum, developing relevant teaching materials, and designing engaging experimental projects in partnership with industry stakeholders.

Thirdly, investing in faculty development is of paramount importance. Universities should focus on enhancing teachers' proficiency in experimental teaching, empowering them to become proactive agents of educational reform and innovation.

Lastly, universities must place students at the center of their efforts. They should create an environment that sparks students' curiosity and motivation, actively involving them in the experimental learning process, and nurturing their practical skills and creativity.

By embracing these insights, universities can effectively implement and enhance their engineering experimental teaching practices, ultimately fostering a dynamic and impactful learning environment for students.

6. Conclusions

Currently, universities face numerous challenges in their engineering experimental teaching, including course design, resource allocation, and teaching methodologies, which hinder the enhancement of teaching quality and effectiveness. These challenges not only emphasize the limited focus on experimental engineering education but also reveal flaws in the experimental teaching framework and administrative practices.

In response, this article introduces a revamped model of engineering experimental teaching that integrates educational and industrial practices, prioritizes students' needs, and aligns with industry standards. By revamping curricula, refining teaching techniques, and enhancing the learning environment, this model effectively elevates the quality and impact of engineering experimental instruction. Its practical implementation fosters students' hands-on skills and creativity while bridging the gap between university engineering education and industry demands. Through rigorous case studies, this article showcases the significant role of the model in raising engineering experimental teaching standards, providing valuable insights for other institutions seeking to enhance their own practices.

Looking ahead, engineering experimental teaching faces both new opportunities and challenges. With the rapid advancement of technology and the evolving industrial landscape, society's expectations for the practical and innovative capabilities of engineering graduates are increasing. As a result, universities must remain agile and continue to innovate in their engineering experimental teaching practices to align with the evolving needs of society. By embracing these opportunities and effectively addressing the challenges, universities can further enhance the quality and relevance of engineering experimental teaching, preparing students for success in their future careers.

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