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RESEARCH ARTICLE

A Review of teaching environment and social factors influencing engineering innovation in Henan vocational students

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ABSTRACT

Engineering innovation ability (EIA) is increasingly recognized as a vital skill set for students in higher vocational education, particularly in the context of Henan, China's rapidly developing industrial landscape where over 150 institutions cater to more than 400,000 students annually. This review utilized content and narrative analysis to synthesize qualitative data from over 50 studies, investigating the social and environmental factors that influence the EIA of higher vocational students, addressing a gap in the literature by examining how educational strategies such as theoretical and practical teaching methodologies, internships and school-enterprise cooperations impact students' innovation capabilities within social and teaching environments. This review revealed that theoretical teaching methodologies (TTM) provide essential foundational knowledge, while practical teaching methodologies (PTM) enhance problem-solving and hands-on skills through real-world applications. Internships (INT) emerged as a critical platform for bridging theoretical concepts with industry practices, fostering adaptability and practical innovation. School-enterprise cooperations (SEC) were found to support collaborative learning and align vocational training with industry needs, enhancing students' readiness for employment and innovation. Innovation platforms were identified as a significant moderating factor, integrating industry challenges into education to amplify the effectiveness of teaching methodologies and collaborations. The findings also highlighted the limited use of data visualization in existing studies and the need for more comprehensive approaches to presenting qualitative insights, contributing to the growing discourse on engineering innovation and emphasize the importance of considering social dynamics and the teaching environment in fostering innovative talent in the region's vocational institutions.

Keywords: theoretical teaching methodologies (TTM); practical teaching methodologies (PTM); internships (INT); school-enterprise cooperations (SEC); innovation platforms (IP); engineering innovation ability (EIA)

1. Introduction

The evolution of higher vocational education has placed increasing emphasis on cultivating engineering innovation abilities among students to meet the demands of contemporary industries. Historically, research in this field has focused on strategies that integrate industry practices with traditional teaching methods, aiming to bridge the gap between theoretical knowledge and practical application[1,2]. Globally, empirical approaches

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have been observed in countries such as Germany where the dual vocational training system integrates classroom instruction with hands-on industrial training[3] and in Finland, where innovation-based learning models prioritize problem-solving in real-world contexts[4]. These systems demonstrate how integrating industry needs with educational strategies can enhance engineering capabilities and prepare students for dynamic industrial landscapes. Parallel to this, significant scholarly attention has been given to fostering innovation through entrepreneurship. For instance, Li et al[5] highlighted the necessity for higher vocational institutions to embrace the era of "mass entrepreneurship and innovation" by developing academic practices that empower students as primary stakeholders in entrepreneurial ventures. These approaches, echoed in entrepreneurial education frameworks in the United States and Denmark, aim to align educational practices with societal and industrial expectations, equipping students with the skills required to drive innovation in emerging sectors[6,7].

Within this evolving landscape, the role of entrepreneurial platforms has gained prominence internationally as an essential foundation for students to cultivate and apply engineering innovation skills. Strengthening these platforms has been shown to support students' individual ambitions while contributing to broader national development goals[8,9]. In countries like Singapore, polytechnic institutions emphasize entrepreneurial platforms through incubation centers that foster innovation and commercialization of student-led projects[10]. Similarly, Japan's focus on innovation clusters enables vocational students to work on cutting-edge industry projects, bridging the gap between education and employment[11]. Collaborations between academic institutions and industries have emerged as key drivers of innovation globally, fostering symbiotic relationships that benefit students, educators and industry stakeholders[12]. Leveraging universities' vast scientific and technological resources has also been proposed as a pathway to establish effective incubation centers, which can act as hubs for student-led entrepreneurial initiatives. These centers, as seen in countries such as the United States and Israel contribute to talent development and provide substantial potential to align educational outcomes with real-world innovation demands[13].

In comparison to international vocation education systems and practices, Henan, located in China's central plains, it has long been regarded as a strategic epicentre of education, particularly in the realm of vocational training. Historically, Henan's geographical centrality and its rich tradition of crafting and innovation have made it an influential hub for the proliferation of vocational schools, fostering a unique synergy between industry needs, the social, teaching environment and educational delivery[14]. Over the past few decades, Henan has been undergoing rapid industrialization. With the emergence of new industries and technological paradigms, there's been a pressing demand for a workforce adept in the latest engineering skills and innovation techniques. This demand is influenced by technical advancements and also by the social environments within which students learn, such as collaborative and peer-driven settings that promote innovation. According to Zhang et al.[15], Henan houses approximately 15% of China's vocational institutions, demonstrating its formidable role in shaping the nation's skilled workforce. Furthermore, these institutions have consistently been recognized for producing graduates who are immediately employable, highlighting the effectiveness of their curriculum in meeting industry standards and their adaptability to social and environmental changes[16].

The significance of socially dynamic innovation platforms in vocational training has grown immensely, offering students practical exposure and hands-on experiences that traditional classroom settings might fail to deliver. In Henan, these innovation platforms are not mere adjuncts to the curriculum but are integral to the teaching methodology. Schools and industries in the region have fostered close ties, enabling an effective integration of theoretical knowledge and its practical application, receiving substantial research attention in recent years. The development of innovative education methods, such as the "double qualified teacher training mechanism", addresses technical skills and also considers the role of social interactions within learning environments, as discussed by Wu et al.[17]. Furthermore, according to the National Bureau of Statistics of China's Yearbook[18], Henan's industrial output has been growing at an average annual rate of 7.3%, outpacing the national average. With its rich mineral resources, diverse industries ranging from machinery, electronics and energy have found their base in Henan. This rapid industrial growth is intertwined with environmental factors, particularly as industries are increasingly influenced by sustainable practices and green technologies, which depend on engineering innovation to adapt to changing environmental conditions.

The industrial growth of a region is intrinsically linked to its need for skilled personnel, especially in specialized domains like engineering. Zhang & Chu[19] in their comprehensive study on China's engineering education observed that regions with accelerated industrial output often experience a proportionate spike in the demand for skilled engineers and technocrats. Moreover, Henan's status as a central transportation hub, given its extensive rail and road network has attracted substantial foreign direct investments. The Henan Provincial Development and Reform Commission highlighted that FDI in the province increased by 9.2% in the past year, with many international tech giants setting up R&D centres. These centers serve as the lookout for technical skills and also seek engineers who can work effectively within social structures, such as collaborative teams and adapt to environmentally conscious innovation practices. Furthermore, as Yang et al.[20] pointed out, Henan's commitment to sustainable development and clean energy has led to the proliferation of green technology industries in the region. Such sectors, being highly reliant on engineering innovation, also depend on environmental factors that influence the direction of innovation, further demonstrating the role of social and environmental aspects in vocational training.

However, this rising demand also uncovers a challenge. While the need for engineering innovators is palpable, whether the current educational infrastructure is equipped to supply this demand remains a question. Recent surveys have indicated a discernible gap between the skills imparted by educational institutions and those demanded by industries[21]. This gap is partially attributed to the lack of focus on social factors in the learning process and the evolving environmental needs of industries, highlighting the importance of incorporating these aspects into vocational training. Despite Henan's prominence, there is limited research addressing how social and environmental factors interact with vocational educational strategies to shape EIA. Furthermore, existing studies often overlook the role of innovation platforms in aligning educational outcomes with industry expectations, leaving a critical gap in understanding how these factors contribute to student readiness for emerging industrial demands. To address these gaps, this study critically reviews the factors influencing EIA with a particular focus on underexplored strategies such as innovation platforms and their ability to align vocational training with dynamic industry requirements. According to the Ministry of Education of the People's Republic of China[22], Henan is home to over 150 higher vocational institutions, catering to more than 400,000 students annually. This figure further indicates the substantial role these institutions play in the educational landscape of the province[23]. These institutions are primarily tasked with producing graduates who are immediately employable and possess the requisite skills that align with industry demands. However, these skills must also include the ability to navigate social learning environments and respond to environmental challenges in the workplace.

The philosophy of higher vocational education, as Schmidtke & Chen[24] elucidated, is to bridge the gap between theoretical knowledge and practical application. In Henan, with its diverse industrial base, this bridge is vital. Studies by Zhang et al.[25] highlight that approximately 70% of graduates from higher vocational institutions in Henan gain employment within the province itself, emphasizing the localized nature of the training and its effectiveness in meeting regional demands. Moreover, these institutions have undertaken numerous cooperations with local industries, creating a synergistic environment that enhances the learning experience. As noted by Liu & Qin[26], such school-enterprise cooperations have allowed students to get firsthand exposure to real-world challenges, fostering innovation not only through technical skill development but also through the social interactions and environmental contexts in which these challenges are situated. This study addresses these gaps by synthesizing existing literature on EIA through a comprehensive review of educational strategies, social dynamics and innovation platforms with focus on Henan, the findings provide actionable insights to improve vocational education specifically for this region. However, there are challenges on the horizon. Despite their prominence, higher vocational institutions in Henan face the daunting task of continually updating their curricula to match the rapid technological advancements and changing industrial requirements[27]. This necessitates a forward-looking approach, integrating both innovation platforms and social and environmental considerations, ensuring that students are not just job-ready but also future-ready.

2. Materials and methods

This study employed narrative and content analysis techniques to conduct a comprehensive literature review examining factors influencing the engineering innovation ability (EIA) of higher vocational education students in Henan, China. Relevant literature was identified from databases including Scopus, Web of Science, Google Scholar and CNKI using search terms such as “engineering innovation ability”, “vocational education”, “Henan”, “theoretical teaching methodologies”, “practical teaching methodologies”, “internships”, “school-enterprise cooperation” and “innovation platforms”. Studies published between 2010 and 2024 were prioritized to ensure both historical and contemporary relevance. The inclusion criteria for the review encompassed studies related to EIA in higher vocational education, focusing on topics such as teaching methodologies, internships, school-enterprise cooperation and the role of innovation platforms. Empirical, theoretical and review studies in English or Chinese were included as studies lacking methodological rigor, or unrelated to vocational education in Henan or comparable regions, or focusing solely on primary or secondary education were excluded. Narrative and content analysis were used to summarize and interpret the findings from the collected literature. This approach facilitated the identification of key factors, trends and challenges affecting EIA within the context of vocational education in Henan, synthesizing existing research to provide a comprehensive understanding of the role of educational strategies and environmental factors in fostering EIA. Moreover, since the study was based entirely on secondary sources, no ethical approval was required.

3. Review results

3.1. The impact of social and environmental factors on teaching methodologies in China’s higher vocational education

The academic research landscape of higher vocational education in China is in a state of continuous evolution, particularly with respect to its teaching methodologies. Vocational education stands as a pivotal element within China's framework for nurturing professional and technical personnel, thereby making the scrutiny of its teaching methodologies imperative for both academic discourse and practical outcomes[28]. Central to this discourse is the critical observation by Xu et al.[29] which suggests that higher vocational education frequently tends to mimic general education. This mimicry is manifest in several ways, including the dearth of distinctive vocational characteristics, an over-reliance on monolithic teaching strategies and a concerning disparity between theoretical knowledge dissemination and its practical application. Additionally, the lack of emphasis on social learning environments, where collaborative and peer-based interactions can foster innovation, contributes to these shortcomings. Such shortcomings undeniably necessitate educational introspection and reform[29].

In respond to these challenges, Zhou[30] conducted a comprehensive examination of students' practical teaching competencies within vocational settings. The study unearthed salient discrepancies in skill application, prompting a re-evaluation of teaching strategies to bridge these gaps. The findings also suggested that incorporating more socially interactive teaching environments, such as group work and peer-learning activities, could significantly improve the practical application of knowledge. Parallelly, Zhao & Ko[31] undertook a rigorous exploration of vocational teaching behaviours, with an acute focus on their congruence with student engagement, representing a key metric integral to ascertaining the effectiveness of teaching methods. Their research elucidated that while there were innovative strides in teaching, alignment with student engagement remained an area warranting further enhancement. Moreover, language teaching within vocational education has been another focal point of scholarly examination. Zhou[30] critically assessed the domain of vocational English teaching, advocating for a recalibration of teaching models. Their assertion revolved around augmenting the applicability of these models to fortify students' practical acumen while ensuring linguistic proficiency.

Furthermore, emerging from these discussions are several new overarching research themes that warrant further exploration. The synthesis of practical and theoretical teaching methodologies emerges as a key research theme, widely regarded as a potential remedy to the current education system inefficiencies[29]. As Xu et al.[29] discerningly point out, the extant educational frameworks often suffer from an imitation of general education, leading to a marked discrepancy between theoretical tenets and their real-world applications. Their research presages a paradigm where the synthesis of these two teaching methodologies might serve as a foundation for the prevailing higher vocational education challenges. Another salient theme is the intricate balance between practical teaching and vocational education. Hu & Huang[32] underscore the significance of crafting a practical curriculum that is not only academically sound but also resonates with the vocational aspirations of the students. Their work alludes to a teaching realm wherein practical teaching is not seen as a standalone entity but is inextricably woven with the fabric of vocational education, thereby making it ripe for innovative educational interventions.

Building upon these themes, the empirical research landscape presents a diverse range methodologies and insights. Yang et al.[33]offers a comprehensive inventory of the multifarious teaching methodologies that populate China's vocational education system. Their work serves as a testament to the diversity of approaches and the need for a more integrated framework that caters to the unique demands of vocational education. Chen[34], in a seminal exposition, ventures beyond mere cataloguing. He postulates that the key to rejuvenating vocational training lies in educational innovations, proposing novel methodologies that disrupt the status quo and foster a more engaging and efficacious learning environment. Complementing this perspective, Zhang[35] offers a meta-analytical foray into the domain, presenting a holistic view of the prevailing teaching paradigms and their potential trajectories. Zhang's[35] analysis highlights the need for vocational education to adapt to technological changes as well as evolving environmental conditions and social structures, further reinforcing the importance of integrating these factors into teaching methodologies.

3.2. Theoretical and practical teaching effects on student's engineering innovation ability

Emerging trends in the realm of engineering education underline a growing emphasis on the intertwined roles of theoretical and practical teaching methodologies. This trend is particularly evident in the arena of engineering-based innovation, where scholars are increasingly exploring the combination between theory and practice to augment students' engineering innovation capabilities as summerised in **Table 1** below. The studies by Chen et al.[36] and Huang et al.[37] provide insightful perspectives on this dynamic, each emphasizing different aspects of how combining theoretical and practical teaching can augment innovation in engineering students. The research conducted by Chen et al.[36] on STEM teaching for the Internet of Things (IoT) Maker Course presents an integrated teaching model that effectively combines theory with practical application. This model highlights the importance of hands-on learning and innovation in practice, demonstrating that an equilibrium between theoretical teaching and practical experiences can substantially elevate students' innovative awareness and practical abilities.

This approach suggests that when students engage in an iterative learning process, where theoretical understanding and practical application mutually inform each other, their capability to innovate, especially in cutting-edge fields like IoT, is significantly enhanced[36]. Meanwhile, Huang et al.[37] explore the realm of practical teaching in rural planning through their "Rural Innovation Workshop." This study focuses on the impact of problem-oriented training and real-life project participation in bolstering students' practical skills. The paper underscores the efficacy of immersing students in real-world challenges, enabling them to apply theoretical knowledge in practical scenarios. This method not only improves their practical competencies but also stimulates their divergent thinking abilities and organizational and management skills. Such an approach not only contributes to the personal development of students as innovative engineers but also aids in driving sustainable rural development initiatives[37].

Zhang et al.[15] broke away from convention by introducing a method that integrates design-based learning with outcome-based education. Their critique of conventional engineering teaching, which often sequesters theoretical knowledge from applied experiences, is particularly resonant. By ensuring students are not only well-versed in theoretical designs but also capable of predicting and achieving tangible outcomes, the approach fine-tunes their innovative muscles specifically for engineering challenges. In essence, a student trained in such a manner would not just understand the theoretical principles of engineering but would also be equipped to apply them innovatively in real-world scenarios.

Shan et al.[38] further underscored this point, illuminating how intertwining theoretical teachings with practical insights from research projects can create engineers with sharper innovative capabilities. In this context, theoretical teachings help students understand core engineering principles, while hands-on research insights guide them to apply these principles in novel, innovative ways. Such a synthesis preps postgraduates to devise unique engineering solutions, fostering adaptability and an increased proclivity for innovative thinking. Pei & Zhang's[39] multi-stage feedback teaching mode for software engineering graduates, built on project-driven competition, presents another compelling argument. The emphasis here is on the dynamic interplay between theory and practice. While theoretical knowledge provides the foundational understanding of software engineering principles, the competitive, project-driven aspect stimulates innovative applications of these principles. Such a model primes students to repeatedly test and refine their engineering concepts, leading to heightened innovation.

Cheng et al.[40] have echoed a similar sentiment, emphasizing that mere theoretical knowledge, while essential, is not sufficient. Their work in the mineral processing engineering domain vouches for the value of practical teaching in incubating an innovative ethos within engineers. Practical experiences immerse students in the nuances and unpredictability of engineering tasks, necessitating inventive problem-solving, thus stimulating engineering-specific innovation. Revilla-Cuesta et al.[41], in their focus on a technical engineering course, reiterated the merits of a multi-stage feedback teaching mode, similar to Pei & Zhang[39]. Their findings emphasize that iterative feedback within a combination of theoretical instruction and practical application serves as a crucible for fostering engineering innovation. By continually refining their understanding and application based on feedback, students are positioned to come up with more innovative Diez-Pascual et al.[42] advocated for the indispensability of practical teaching by designing simulation tools for photovoltaic energy engineering. By leaning heavily into real-world scenarios, they showcased the direct correlation between practical teaching in rural planning and the ability of students to stay competitive and innovative in the broader societal framework. Essentially, students are not just digesting theoretical knowledge but are applying it in a tangible setting, honing their innovative capabilities. Daaif et al.[43] introduced a pedagogical shift by infusing three-dimensional digital modelling in teaching practical experiments of chemistry. Their approach emphasized how innovative teaching, especially from a sustainability standpoint, can profoundly impact students' adaptability and innovative spirit. This not only underscores the significance of merging theoretical foundations with advanced practical tools but also accentuates the importance of aligning teaching methodologies with sustainable development goals, which is intrinsically tied to engineering innovation.

Henkel et al.[44] presented their findings on the teaching of bioprocess engineering to undergraduates. They centred on hands-on training in a practical course spanned over a week. Their study reaffirmed the sentiment that hands-on practical exposure is crucial for instilling an innovative ethos in students. Through multidisciplinary engagements, students could grasp complex engineering concepts in their entirety and were better positioned to innovate within the domain. Sunderland et al.[45] tackled engineering ethics, extending its teaching beyond mere academic confines to international borders. Their multi-stage feedback teaching approach accentuates how iterative feedback, rooted in both theoretical discourse and practical application, can mould graduate students into more innovative thinkers. Such a feedback mechanism continually refines a student’s theoretical understanding and its real-world application, fostering innovative solutions with a global perspective.

Towns & Ashby[46], much like Diez-Pascual et al.[43], emphasized the value of practical teaching in rural planning. Their phenomenological study on occupational therapy students elucidated how practice educators significantly influence the students’ ability to understand and apply theoretical knowledge. The very nexus between the theoretical constructs of their discipline and their real-world application appears to be mediated and enhanced by practical teaching. In general, empirical academic studies recognises the apparent synergy between theoretical grounding and practical experience in engineering education. These studies collectively champion the need for an educational approach that doesn't segregate theory from application but instead combine them in a manner conducive to fostering engineering innovation. The apparent research gap pertaining to Chinese higher vocational education underscores a need for further research in that specific domain to ensure a holistic understanding of the landscape.

Table 1. Theoretical and practical teaching effect on engineering innovation amongst students.

Title	Authors	Year	Key Findings
STEM Teaching for the Internet of Things Maker Course: A Teaching Model Based on the Iterative Loop	Chen et al.	2020	The study presents a teaching model that integrates theory, practice and innovation for IoT maker courses. It emphasizes the importance of practical learning and innovation in practice, showing that this approach can improve the effectiveness of theoretical teaching and cultivate students’ innovative awareness and practical abilities.
Insight into Practical Teaching in Rural Planning in Colleges Based on the “Rural Innovation Workshop”	Huang et al.	2022	This paper explores the impact of practical teaching in rural planning through the “Rural Innovation Workshop.” It highlights the importance of problem-oriented training and real-life project participation to improve students’ practical skills, divergent learning

Table 1. (*Continued*)

Title	Authors	Year	Key Findings
			abilities and their capacity for organization and management, thereby promoting rural development.
Application of Design-Based Learning and Outcome-Based Education in Basic Industrial Engineering Teaching: a new teaching method	Zhang et al	2021	The study found that combining design-based learning and outcome-based education can improve the shortcomings of traditional teaching methods, which often concentrate on the teaching of theoretical knowledge and neglect the cultivation of practical ability.
The development and teaching of the postgraduate course "Engineering System Modelling and Simulation" in combination with essentials taken from research projects	Shan et al.	2023	The study found that enforcing the relationship between theoretical and practical teaching can enhance the ability of postgraduates to adapt to social competition and develop their innovation ability.
Exploring a multi-stage feedback teaching mode for graduate students of software engineering discipline based on project-driven competition	Pei & Zhang	2022	The study found that a multi-stage feedback teaching mode can enhance the ability of graduate students to adapt to social competition and develop their innovation ability.
Practicing education of the mineral processing engineering discipline in Henan Polytechnic University	Cheng et al.	2019	The study found that practical teaching is important for the cultivation of a spirit of innovation and to enhance the practical engineering abilities of students.
Student perceptions of formative assessment and cooperative work on a technical engineering course	Revilla-Cuesta et al.	2020	The study found that a multi-stage feedback teaching mode can enhance the ability of graduate students to adapt to social competition and develop their innovation ability.
Design of simulation tools for teaching in photovoltaic energy engineering	Diez-Pascual et al.	2018	The study found that practical teaching in rural planning can enhance the ability of students to adapt to social competition and develop their innovation ability.
Pedagogical engineering to the teaching of the practical experiments of chemistry: development of an application of three-dimensional digital modelling of crystalline structures	Daaif et al.	2020	The study found that college teaching innovation from the perspective of sustainable development can enhance the ability of students to adapt to social competition and develop their innovation ability.
Teaching bioprocess engineering to undergraduates: Multidisciplinary hands-on training in a one-week practical course	Henkel et al.	2015	The study found that practical teaching is important for the cultivation of a spirit of innovation and to enhance the practical engineering abilities of students.
Teaching global perspectives: engineering ethics across international and academic borders	Sunderland et al.	2014	The study found that a multi-stage feedback teaching mode can enhance the ability of graduate students to adapt to social competition and develop their innovation ability.
The influence of practice educators on occupational therapy students' understanding of the practical applications of theoretical knowledge: a phenomenological study into student experiences of practice education	Towns & Ashby	2014	The study found that practical teaching in rural planning can enhance the ability of students to adapt to social competition and develop their innovation ability.

3.3. The effects on internship on student's engineering innovation ability

The ever-evolving landscape of engineering education is continually met with challenges and solutions alike. An emerging trend in this paradigm is the incorporation of internships as a pedagogical tool to foster engineering-based innovation. This hands-on approach, diverging from the confines of traditional classroom learning, brings forth practical exposure and experiential learning, aiming to nurture the innovative spirit of engineering students as shown in the empirical studies summerised in **Table 2** below. Babamohamadi et al.[47] conducted a study identifying strategies used by senior nursing students to adjust to internship conditions, especially in the absence of a full-time trainer. This research suggests that addressing the root causes of these strategies, particularly the negative ones, is essential for helping students adjust and acquire necessary clinical competency. This finding is crucial as it implies that the quality of internship experiences, including the availability of adequate guidance and support, can significantly influence the development of students' innovation abilities in practical settings[47].

Table 2. Internship effects on engineering innovation ability.

Title	Authors	Year	Key Findings
Strategies used by Iranian nursing students for adjusting to internship: a qualitative study.	Babamohamadi et al.	2023	The study identified strategies used by senior nursing students to adjust to internship conditions in the absence of a full-time trainer. It suggests that nursing authorities should address the root causes of these strategies, especially negative ones, to help students better adjust and acquire the necessary clinical competency.
Psychological experience among internship nurses at different internship stages: A qualitative study.	Xiong & Zhu	2023	This study explores the psychological experiences of nursing interns in China, highlighting the emotional challenges and stress associated with clinical practice. It emphasizes the need for support mechanisms to help students transition from theoretical learning to practical patient care and management.
The Readiness for Interprofessional Education (IPE) In The School Setting Among The Internship Students Of Applied Medical Sciences At Taibah University	Salih et al.	2022	The research found that the majority of internship students agreed that IPE enhances cooperation and teamwork skills. However, there was some disagreement about the negative professional identity of IPE, with some students considering it a waste of time.
Caring ability of nursing students pre- and post-internship: a longitudinal study	Hu et al.	2022	This longitudinal study assessed the caring ability of nursing students before and after their internship. The findings suggest that internships have a significant impact on the development of students' caring abilities, which are crucial for their future roles as nurses.
Changes in professional commitment of undergraduate nurse students before and after internship: a longitudinal study	Zhao et al.	2022	The study examined the professional commitment of undergraduate nursing students before and after their internships. It found that internships play a critical role in shaping students' professional identities and commitment to the nursing profession.
A project-based learning approach to promote innovation and academic entrepreneurship in a master's degree in engineering	Oliveira & Cardoso	2021	The study found that internships can help students develop the skills and competences to articulate knowledge acquired during their training in Engineering with the needs of Society through business development and the creation of new companies based on knowledge and innovation.
Engineering Students' Industrial Internship Experience Perception and Satisfaction: Work Experience Scale Validation	Nogueira et al.	2021	The study found that internships can enhance the ability of engineering students to adapt to industrial work environments and develop their innovation ability.
International Industrial Internship: A Case Study from a Japanese Engineering University Perspective	Tan & Umemoto	2021	The study found that international internships can enhance the ability of engineering students to adapt to different work cultures and develop their innovation ability.

Table 2. (*Continued*)

Title	Authors	Year	Key Findings
Sustainable Development of Employability of University Students Based on Participation in the Internship Promotion Programme of Zhejiang Province	Chen & Gan	2021	The study found that internships can enhance the employability of engineering students and develop their innovation ability.
Investigating the Experiences, Beliefs and Career Intentions of Historically Underrepresented Science and Engineering Undergraduates Engaged in an Academic and Internship Program	McAlexander et al.	2022	The study found that internships can enhance the career intentions of engineering students and develop their innovation ability.
A novel paradigm for engineering education: Virtual internships with individualized mentoring and assessment of engineering thinking	Chesler et al.	2015	The study found that virtual internships can help students develop engineering knowledge, interest in and motivation to pursue an engineering degree and confidence in their ability to do professional engineering work.
Effects of internship on fresh graduates: A case study on IIT, DU students	Ami et al.	2020	The study found that internships can enhance the ability of fresh graduates to adapt to work environments and develop their innovation ability.
Effects of summer internship and follow-up distance mentoring programs on middle and high school student perceptions and interest in health careers	Fernandez-Repollet et al.	2018	The study found that summer internships can enhance the interest of middle and high school students in health careers and develop their innovation ability.
An internship may not be enough: Enhancing bioscience industry job readiness through practicum experiences	Cramer & Hamilton	2017	The study found that internships can enhance the job readiness of bioscience students and develop their innovation ability.
Ontology-based system to guide internship assignment process	M'Baya et al.	2016	The study found that an ontology-based system can enhance the internship assignment process and develop the innovation ability of students.

Xiong & Zhu[48] explored the psychological experiences of nursing interns in China, focusing on the emotional challenges and stress associated with clinical practice. Their study emphasizes the need for support mechanisms to assist students in transitioning from theoretical learning to practical patient care and management. This finding highlights the importance of psychological preparedness as a component of innovative capability in clinical settings, suggesting that internships that provide emotional support and stress management can enhance students' ability to innovate in their future roles.

Salih et al.[49] investigated the Readiness for Interprofessional Education (IPE) among internship students in applied medical sciences. Their research found that while most internship students acknowledged the benefits of IPE in enhancing cooperation and teamwork skills, there were concerns regarding its impact on professional identity. This study underscores the need for well-structured internship programs that balance skill development with professional identity formation, which are both critical for fostering innovation in engineering students. Hu et al.[50] conducted a longitudinal study assessing the caring ability of nursing students pre- and post-internship. Their findings suggest that internships significantly impact the development of students' caring abilities, crucial for their future roles as nurses. This study indicates that internships can profoundly influence the soft skills of students, which are essential for innovation in patient care and healthcare management.

Zhao et al.[51] examined the changes in professional commitment of undergraduate nursing students before and after their internships. The study found that internships play a critical role in shaping students' professional identities and commitment to the nursing profession. This finding is significant as it implies that internships not only equip students with technical skills but also foster a deeper sense of professional dedication, which is a key driver of innovation in any field, including engineering. Oliveira & Cardoso[52] addressed the importance of internships in a master's engineering program, suggesting that such real-world experiences equip students with the skills to bridge the theoretical knowledge acquired in classrooms with societal needs. The study highlighted an interesting dimension, the ability of internships to inspire entrepreneurial ventures rooted in knowledge and innovation. The translation of academic prowess into business development and startup creation elucidates the power of internships in stimulating the entrepreneurial and innovative facets of engineering students.

Nogueira et al.[53] extended the dialogue by emphasizing the alignment between internships and adaptability to industrial environments. Engineering, being an applied discipline, demands that students are well-acquainted with the nuances of industry dynamics. The findings suggest that internships offer an ideal platform for students to immerse themselves in real-world engineering challenges, thereby enhancing their innovative capacities and making them industry-ready. A cross-cultural dimension to internships was presented by Tan & Umemoto[54]. Through the lens of a Japanese Engineering University, they revealed that international internships offer twofold benefits including cultural adaptability and innovative ability enhancement. Operating in diverse work cultures demands a higher level of creative problem-solving, which inadvertently boosts the innovative capabilities of the students.

Chen & Gan[55] critically explored the sustainable employability of engineering students as they participated in Zhejiang Province's Internship Promotion Programme. Beyond the immediate skill acquisition, internships, as this study indicates, lay the groundwork for future employability, with innovation ability acting as a linchpin. This dual benefit showcases the value of internships in immediate educational outcomes and long-term career prospects. McAlexander et al.[56] provided a more focused perspective, examining underrepresented engineering undergraduates. Their findings indicate that internships not only strengthen the innovation ability of these students but also bolster their career intentions. The pivotal role of internships in inclusivity and creating a level playing field can't be understated.

Chesler et al.[57] introduced a forward-thinking paradigm to the internship model via the concept of virtual internships. In an age where digital transformation shapes almost every sector, the study underscores the efficacy of virtual internships in cultivating engineering acumen and fostering a genuine interest in the field. Furthermore, these virtual platforms enhance students' confidence, allowing them to navigate professional engineering tasks effectively. Such confidence, rooted in practical experience can be digitally mediated, thus becoming instrumental to drive innovation, as students are more inclined to think outside the box when they believe in their capabilities. Ami et al.[58] from IIT and DU shed light on the transitional phase of fresh graduates. Their findings reiterate the significant influence internships wield in smoothing this transition. As these fresh graduates adapt to professional environments, their exposure during internships strengthens their innovative capacities. The transition from academic settings to real-world challenges inevitably spurs innovative thinking, primarily when facilitated through internships.

Fernandez-Repollet et al.[59] broadens the scope by looking at middle and high school students, focusing on their interest in health careers. While the study centres on health careers, the takeaway about summer internships fostering innovation is universal. Early exposure, as offered by these internships, plants the seeds of innovative thinking, potentially beneficial when these students eventually pursue engineering or any other discipline. Cramer & Hamilton's[60] study in 2017 addressed the bioscience terrain, but its findings resonate with the overarching theme of enhancing job readiness through internships. Such readiness invariably includes an ingrained ability to think innovatively, a skill honed through real-world experience. While bioscience and engineering are distinct fields, the role of internships in shaping innovation stands consistent.

M'Baya et al.[61] critically adopted a more structured approach to exploring the effects of internships. By harnessing ontology-based systems, their study aimed to optimize the internship assignment process. A well-matched internship could exponentially enhance a student's experience, subsequently cultivating their innovative spirit. This structured approach ensures that students are placed in environments conducive to their innovative growth. Under the general research consensus, the role of internships, whether conducted virtually or in-person, undeniably play a pivotal role in moulding an engineering student's innovative prowess. Bridging the gap between theoretical knowledge and real-world challenges, these experiences foster an environment where students can test, iterate and innovate. As the engineering domain advances, integrating such practical experiences into education curricula represents vital importance in the research field.

3.4. School-enterprise cooperation effects on student's engineering innovation ability

The emergent trend of utilizing school-enterprise cooperation as a pedagogical strategy to cultivate engineering innovation abilities draws from the overarching shift in academic paradigms towards real-world applicability and industry alignment as summerised in **Table 3**. Yao et al.'s[62] exposition on China's innovation and entrepreneurship pilot demonstration policy bears testament to the power of institutional support in innovation cultivation. While the paper primarily revolves around the construction of the Innovation and Entrepreneurship Demonstration Bases (IEDB), the underlying premise of government backing in key innovation areas resonates with the ethos of school-enterprise cooperation. When academic institutions are buttressed by external entities be it the government or enterprises, the environment is invariably more conducive for innovation to thrive. It also demonstrates the potential of a spillover effect, where innovative practices in one institution can influence others, drawing parallels to the diffusion role enterprises can play in academia.

Table 3. School-enterprise cooperation effects on engineering innovation ability.

Title	Authors	Year	Key Findings
Effects of government innovation support on the innovation ability of universities: Evidence from the quasi-natural experiment of China's innovation and entrepreneurship pilot demonstration policy	Yao et al.	2023	The study found that the construction of the Innovation and Entrepreneurship Demonstration Bases (IEDB) provides a good institutional environment for the development of innovation and entrepreneurship in China. It can also play an innovative diffusion role for other regions and industry–university research subjects through government support in the key areas of innovation and entrepreneurship.
Innovation-based learning (InnBL): Turning science and engineering undergraduate degree programmes toward innovation	Mandumpal et al.	2022	The study found that innovation-based learning can turn science and engineering undergraduate degree programmes toward innovation.
Influence of students' ability to delay gratification on their educational transition choice	Ganie	2022	The study found that the ability of students to delay gratification can influence their educational transition choice.
Developing innovation competences in engineering	Charosky et al.	2021	The study found that developing innovation competences in engineering students can be achieved through different

Table 3. (*Continued*)

Title	Authors	Year	Key Findings
students: A comparison of two approaches			approaches.
The innovation level of engineering students' team projects in hybrid and MOOC environments	Barak & Usher	2022	The study found that the innovation level of engineering students' team projects can be influenced by hybrid and MOOC environments.
Cooperation between universities, governments and industries: applying the triple helix relationship model to Indonesian education improvement.	Wu & Siswanto	2020	The study found that the interaction between university, industry and government can enhance the innovation and entrepreneurship ecosystem in higher education institutions.
Two sides of the same coin, university-industry cooperation ad open innovation as enhancers of firm performance	Costa et al.	2021	The study found that university-industry cooperation can have a positive impact on innovation and firm performance in the renewable energy sector.
Practice and Thinking of Constructing School-enterprise Cooperation and Innovative Talent Training System for New Engineering	Shi et al.	2021	The study explores the practice and thinking behind constructing a school-enterprise cooperation and innovative talent training system for new engineering. It emphasizes the importance of cooperation between educational institutions and industry to foster innovation and talent development.
Exploration and practice of school-enterprise cooperation in practical education based on "outstanding project"	Li et al.	2013	This study explores into the exploration and practice of school-enterprise cooperation in practical education, focusing on the "outstanding project" approach. It highlights the significance of practical experiences in enhancing students' innovation abilities.
Theoretical and practical method of school-enterprise cooperation and training innovative engineering talents	Jiancheng et al.	2012	The study presents a theoretical and practical method for school-enterprise cooperation aimed at training innovative engineering talents. It underscores the importance of bridging the gap between academia and industry to cultivate innovation among students.

Mandumpal et al.[63] critically explores into innovation-based learning, underscoring its efficacy in redirecting science and engineering curricula towards innovation. The study, although not explicitly focused on school-enterprise cooperation, exudes relevance. Innovation-based learning often requires real-world applications and enterprises can be pivotal in offering these practical scenarios. The synergy between academic tenets of innovation and industry-relevant challenges, facilitated by enterprises, can be instrumental in honing student innovation abilities. Ganie's[64] exploration of students' ability to delay gratification and its bearing on educational transition choices might, at first glance, seem tangential to school-enterprise cooperation. However, when one considers the patience and perseverance often required in real-world enterprise scenarios, the link becomes evident. Effective school-enterprise cooperation can instil these attributes in students, thus influencing their educational trajectories and, by extension, their innovative capabilities.

Charosky et al.[65] broach the topic of innovation competences and highlight the multiplicity of paths to its attainment in engineering students. This plurality suggests the possibility of varied interactions between academia and enterprises, each catering to different innovation competencies. It's an implicit affirmation that the nuances of school-enterprise cooperation can significantly influence the innovation spectrum. Alternatively, Barak & Usher[66] investigates the complexity of learning environments, particularly the hybrid and MOOC formats and their bearing on the innovation level of team projects. In an era where digital transformation and remote cooperations are becoming the norm, enterprises to operate in hybrid modalities.

This aligns well with school-enterprise cooperation, as students trained in these environments are better equipped to navigate the innovation challenges of contemporary enterprises.

Wu & Siswanto[67] directed their study towards the triple helix relationship model involving universities, governments and industries, with particular relevance to the Indonesian educational paradigm. The pivotal takeaway is that the symbiotic interaction among these tripartite entities can substantially elevate the innovation and entrepreneurship framework in tertiary educational bodies. In essence, it accentuates the overarching role of a cooperative trinity including university, industry and government, especially in forming a robust innovation dynamic, which is an essential corollary for enhancing engineering innovation ability in students. Costa et al.[68] engaged in an exploration of the dual facet of university-industry cooperation and open innovation, particularly within the context of the renewable energy sector. The crux of their study elucidates that such collaborative ventures can be pivotal in accentuating both innovation and the overall performance metrics of firms. The implications for engineering education are profound; cooperation with industries can offer students exposure to cutting-edge technological advancements, thereby fostering an innovative mindset that is attuned to real-world challenges.

The study by Shi et al.[69] brings to the fore the quintessence of crafting a school-enterprise cooperative model specifically oriented towards innovative talent training in the sphere of new engineering. Through emphasizing the imperative nature of partnerships between academia and the industrial sector, it underlines the potential these alliances hold in nurturing innovation and fostering a reservoir of talented engineers poised to address contemporary challenges. Li et al.'s[70] work underscores the pertinence of hands-on experiences in refining students' innovative capacities. Through elucidating the "outstanding project" approach, their research accentuates the confluence of theoretical knowledge with practical insights garnered from industry cooperations. Such an integrative approach not only bolsters innovation ability but also ensures that students are primed to navigate the challenges of modern engineering landscapes.

A study by Jiancheng et al.[71] provide both a theoretical blueprint and practical methods encompassing school-enterprise cooperation. The key insight drawn is the indispensability of bridging the academia-industry chasm to foster an innovative ethos among budding engineers. It serves as a potent reminder that theoretical acumen, when complemented with practical industry insights, can create a cohort of engineers proficient in innovative thinking. In summation, the burgeoning realm of research spotlighting the role of school-enterprise cooperation in augmenting engineering innovation abilities is a testament to its cardinal importance. The growing body of literature underscores that this interface is not a mere supplementary aspect of education but a cornerstone for nurturing the innovative prowess of future engineers. As this research area continues to expand, its findings are becoming increasingly central to informing pedagogical practices in engineering institutions globally.

3.5. The role of innovation platforms between practical teaching methodologies and engineering innovation in higher vocational education

The development of the open innovation theory (OIT) by Chesbrough[72] marked a pivotal transition in understanding the dynamics of innovation processes, propounding a departure from traditionally insular strategies of innovation, which predominantly relied on internal resources. According to Chesbrough[72], the modern innovation process is driven by a more integrative approach, advocating for the harnessing of both internal and external avenues of knowledge to drive forward the wheels of innovation. Another study by Yordanova[73] further expanded upon the origins of the open innovation theory into the application of education, proposing an open innovation driven educational model as shown in **Figure 1** below. According to Yordanova[73], the open education innovation model posits that education systems can employ open innovation for improving educational performance in areas of research, management, competitiveness, human progress, knowledge transfer and innovation, representing a key metric in measuring open innovation in education.

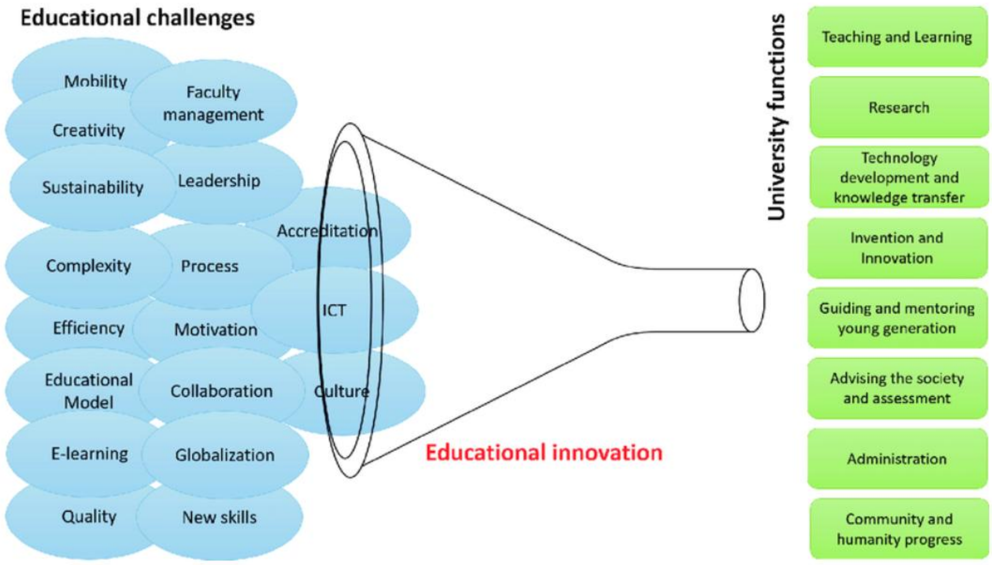

Figure 1. Open education innovation model (Yordanova[73]).

In the context of vocational education, innovation platforms can be understood as structured environments, both digital and physical, where students, educators, industry experts and other stakeholders collaboratively engage in problem-solving, ideation and innovation processes[74]. Rooted in the open innovation theory, these platforms emphasize collaborative efforts and incorporate both internal pedagogical insights and external industry expertise to foster innovation. Moreover, the open innovation theory posits that for maximum innovation efficiency, educational institutions should harness both external and internal ideas. In a vocational education setting, practical teaching methodologies provide students with foundational knowledge and skills. However, when this teaching is augmented with the external inputs available through innovation platforms, the innovation potential is significantly amplified[75].

Additionally, empirical studies have shown that innovation platforms in vocational education settings can act as catalysts for innovation. Gassmann & Enkel[76] highlighted how these platforms create an interface for students to interact with real-world industry challenges, fostering an innovative mindset. Furthermore, their study found that when students in vocational training programs are exposed to practical challenges via these platforms, their ability to ideate, prototype and innovate is considerably enhanced. Another seminal study by Laursen & Salter[77] further explored the mechanisms through which open innovation practices, symbolized by innovation platforms, could foster creativity and innovative output. Their study found that people exposed to open innovation environments, where external knowledge sources were accessible, displayed heightened levels of problem-solving capabilities and inventiveness. This study provided early empirical support for the transformative potential of open innovation platforms.

The study by Dahlander & Gann[78] offered another perspective in the investigation of innovation platforms in the domain of education, finding that innovation platforms facilitated not just the absorption of external knowledge but also its dissemination. Students involved in such platforms were more adept at transferring their academic learnings to real-world contexts, thus bridging the often-lamented theory-practice gap. Their findings echo the theoretical propositions of Chesbrough[72] by demonstrating that the bidirectional flow of innovative knowledge, both into and out of the academic institution. In the specific context of higher vocational education, a study by Lee et al.[79] supported the role of innovation platforms in enhancing the entrepreneurial spirit among students. Through immersing students in a practical environment, supplemented by inputs from industry experts and external stakeholders, the innovation platforms nurtured a mindset conducive to entrepreneurial thinking and innovation. Such findings are pivotal, given the increasing emphasis on entrepreneurship in the modern job market.

However, it's worth noting that the successful integration of open innovation in educational settings is not without its challenges. A study by Trott & Hartmann[80] highlighted potential pitfalls, including the risk of knowledge overload and difficulties in filtering relevant information. Hence, while innovation platforms offer immense potential benefits, it's essential for educational institutions to design and manage them effectively, ensuring they align with pedagogical goals while avoiding potential pitfalls. Moreover, when investigating the moderating role of innovation platform between practical teaching methodologies and stimulated innovation, Huizingh's study[81] provided valuable insights on the moderating influence of innovation platforms, finding that it would enhance the effects of practical teaching methodologies by introducing students to external industry challenges and expertise. The combination of internal academic rigor and external industry insights, as emphasized by the open innovation theory, paves the way for a richer, more applied and innovative learning experience via innovation platforms. Based on this empirical and theoretical knowledge, the following research hypothesis is proposed.

3.5.1. The role of innovation platforms between theoretical teaching methodologies and engineering innovation in higher vocational education

Innovation platforms could potentially play a pivotal role in linking theoretical teaching methodologies with engineering innovation in higher vocational education, as these platforms provide a digital or physical space where theoretical concepts can be explored and applied through simulations, collaborative projects and interactive learning modules. Through integrating real-world scenarios and problems, innovation platforms help students transform abstract theories into practical solutions, fostering a deeper understanding of engineering principles and sparking innovative thinking.

3.5.2. The role of innovation platforms between internship and engineering innovation in higher vocational education

Innovation platforms can also potentially bridge internships and engineering innovation, creating synergies that enhance learning outcomes, as these platforms allow students to share their internship experiences and apply their on-the-job learning to simulate and real-time projects, thereby reinforcing their practical skills. Moreover, they provide a repository of industry challenges and solutions that students can access to enrich their understanding and contribute innovative ideas, thus accelerating the transition from novice to innovative engineer.

3.5.3. The role of innovation platforms between school-enterprise cooperations and engineering innovation in higher vocational education

It is recognised that innovation platforms could serve as crucial conduits for school-enterprise cooperations, enhancing engineering innovation in higher vocational education. Through facilitating efficient interaction between academic institutions and industry partners, enabling the co-creation of curricula and joint projects that reflect current industry standards and innovations. From the provision of continuous exchange of expertise and resources, innovation platforms ensure that students gain relevant, up-to-date knowledge and skills, ultimately leading to groundbreaking innovations in engineering practices.

4. Conceptual framework

The conceptual framework in **Figure 2** outlines the interconnected social and environmental factors that influence both the teaching and learning environment, impacting the engineering innovation ability (EIA) of higher vocational students in Henan, China, integrating theoretical teaching methodologies (TTM), practical teaching methodologies (PTM), internships (INT) and school-enterprise cooperations (SEC) as primary determinants that directly shape students' innovation capabilities. The framework emphasizes that TTM and PTM are shaped by social factors such as collaboration, teamwork and peer engagement, all of which contribute to a socially dynamic learning environment where innovation is fostered through interaction and group-based learning. INT and SEC also operate within these social contexts, where internships and partnerships with enterprises encourage students to engage with industry professionals, thus reinforcing their innovation abilities through real-world social networks and collaborative problem-solving. Moreover, the environmental context plays a crucial role. As industries increasingly adopt sustainable practices, vocational education must integrate environmental considerations into PTM and SEC, preparing students to address industry challenges related to environmental sustainability. The framework highlights how innovation platforms (IP) serve as a bridge, moderating the relationship between these teaching practices and industry needs, particularly in environments where sustainability and green technologies are paramount. IPs provide students with opportunities to apply their learning in environmentally conscious contexts, further enhancing the effectiveness of TTM, PTM, INT and SEC in cultivating EIA. Through systematically combining these elements, the framework illustrates a comprehensive model that reflects the interaction between educational strategies and industry requirements while being influenced by overarching social and environmental factors. This model offers insights into optimizing innovation outcomes in vocational training through a deeper understanding of how social dynamics and environmental conditions shape both teaching and learning.

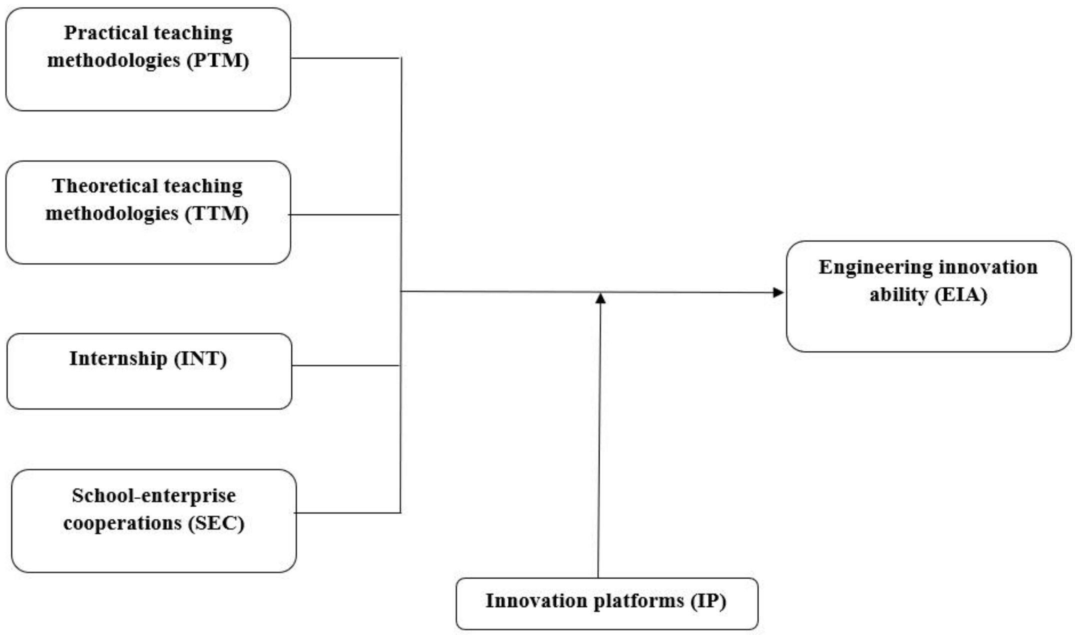

Figure 2. Conceptual framework.

5. Conclusion

The findings of this review demonstrate the potential of educational strategies including theoretical teaching methodologies, practical teaching methodologies, internships and school-enterprise cooperations is demonstrated in their ability to foster engineering innovation ability (EIA) among students in higher vocational education institutions. The review revealed that TTM provides foundational knowledge essential for technical understanding, while PTM enhances problem-solving skills through experiential learning approaches, such as workshops and hands-on projects. INT emerged as a critical bridge between theory and practice, equipping students with practical insights and adaptability in real-world industrial settings. SEC was found to be highly effective in fostering collaboration between schools and industries, facilitating curriculum alignment with industry needs and providing students with exposure to contemporary challenges in engineering practices. Additionally, innovation platforms were identified as a moderating factor that significantly amplifies the effectiveness of these strategies. These platforms integrate real-world industry challenges into educational processes, enabling students to engage in collaborative projects that enhance teamwork, sustainability and industry-driven problem-solving. For instance, case studies highlighted the role of innovation platforms in providing access to advanced technology and fostering multi-disciplinary projects that encourage innovative thinking. This integration, particularly when aligned with social and environmental contexts, creates a holistic and applied learning environment, bridging the gap between educational outcomes and industry requirements.

Furthermore, the synergy between these educational strategies and external inputs from industry enables students to develop comprehensive and up-to-date engineering skills. This review also addresses the importance of embedding social collaboration and environmental awareness into vocational training, with findings indicating that these elements enhance students' readiness to address sustainability challenges and contribute to green innovation. Overall, the findings of this review provide a roadmap for enhancing EIA in higher vocational education and highlights the necessity of combining diverse teaching methodologies with industry engagement within the broader social and environmental landscape to maximize innovation potential. Continuous research and development are essential to refine these educational strategies further as the findings suggest that targeted efforts to expand the use of innovation platforms, particularly those that support interdisciplinary collaboration and sustainability-focused projects, will be key to advancing vocational education. This will ensure the production of future-ready engineering innovators capable of addressing complex industrial and environmental challenges.

6. Significance and benefits of study

The significance of this study lies in its comprehensive examination of factors affecting the engineering innovation ability (EIA) of higher vocational education students in Henan, China, an area where research is notably sparse. Despite the growing emphasis on fostering engineering innovation to meet the demands of Henan's rapidly evolving industries, a conspicuous gap exists in the literature addressing how educational strategies can enhance these capabilities specifically within this context. This study considers the impact of social learning environments and environmental factors, especially their role in shaping vocational education strategies, focusing on theoretical and practical teaching methodologies, internships and school-enterprise cooperations, this research provides unique insights into optimizing educational practices for developing innovation capabilities in engineering students, tailored to the industrial and educational landscape of Henan. Similar reviews in the context of Henan's vocational education system are limited, even though the region has become increasingly recognized for its industrial growth and demand for innovative engineering talent. The study also emphasizes the critical role of innovation platforms as a moderator that bridges the theoretical-practical gap, ensuring that students are equipped to address complex, real-world engineering challenges while also navigating the social and environmental expectations of modern industries. The research framework presented here addresses this overlooked aspect, laying a foundation for further exploration of effective strategies to nurture engineering innovation in Henan's vocational institutions. Ultimately, the insights gained from this review highlight the significance of a targeted and context-specific approach to cultivating innovation in engineering education, supporting the ongoing development of vocational training to produce highly skilled, innovative professionals equipped for the evolving social and environmental challenges of Henan's industrial landscape.

Conflict of interest

No conflict of interest was reported by all authors.

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