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# DEVELOPING ENGINEERING STUDENTS' COMPETENCIES THROUGH CRITICAL THINKING: A METHODOLOGICAL APPROACH

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**Abstract.** This article examines the role of critical thinking in the development of engineering students' competencies within the framework of modern higher education. The study highlights the growing importance of competency-based education in preparing future engineers for the challenges of a rapidly changing technological environment. Particular attention is given to the pedagogical methods that promote critical thinking, including problem-based learning, project-based learning, case study analysis, collaborative learning, and the integration of digital technologies. The article analyzes the theoretical foundations of critical thinking and its contribution to the formation of professional, analytical, and decision-making competencies. The findings suggest that a systematic integration of critical thinking into engineering curricula enhances students' ability to solve complex problems, evaluate information critically, and adapt to contemporary professional demands. The study concludes that critical thinking is a key factor in improving the quality and effectiveness of engineering education and in preparing competent and innovative engineering professionals.

**Keywords.** Engineering education, critical thinking, competency-based education, engineering competencies, problem-based learning, project-based learning, higher education, professional skills, analytical thinking, decision-making, innovative learning methods, engineering students.

**Introduction.** In the context of rapid technological advancement, globalization, and the increasing complexity of engineering challenges, the role of engineering education has expanded beyond the traditional transmission of technical knowledge. Modern engineers are expected not only to possess strong professional expertise but also to demonstrate critical thinking, problem-solving abilities, creativity, communication skills, and the capacity to make informed decisions in complex and uncertain situations. Consequently, higher education institutions are increasingly focusing on the development of competencies that enable engineering graduates to adapt to the dynamic demands of the twenty-first-century labor market.

Critical thinking has emerged as one of the most important competencies in contemporary engineering education. It refers to the ability to analyze information objectively, evaluate evidence, identify assumptions, formulate logical arguments, and make reasoned judgments. In engineering practice, critical thinking plays a crucial role in solving technical problems, designing innovative solutions, assessing risks, and ensuring the reliability and sustainability of engineering projects. Engineers frequently encounter situations where they must interpret complex data, consider multiple alternatives, and make decisions that have significant economic, environmental, and social implications. Therefore, fostering critical thinking skills among engineering students has become a priority for educational institutions worldwide.

The growing emphasis on competency-based education has further highlighted the importance of integrating critical thinking into engineering curricula. Competency-based education focuses on the development of measurable knowledge, skills, attitudes, and behaviors that students need to perform effectively in professional environments. Unlike traditional educational models that primarily emphasize content acquisition, competency-based approaches encourage active learning, independent inquiry, and practical application of knowledge. Within this framework, critical thinking serves as a

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foundation for the development of both technical and transferable competencies, enabling students to become more effective learners and future professionals.

Recent educational research has demonstrated that traditional lecture-based teaching methods often fail to provide sufficient opportunities for students to engage in higher-order thinking processes. As a result, educators have increasingly adopted innovative pedagogical strategies such as problem-based learning, project-based learning, case study analysis, collaborative learning, and inquiry-based instruction. These approaches encourage students to analyze real-world engineering problems, evaluate alternative solutions, and reflect on their decision-making processes. Through such learning experiences, students can develop critical thinking skills while simultaneously strengthening their professional competencies.

Furthermore, the digital transformation of industry and the emergence of technologies associated with Industry 4.0 have created new expectations for engineering graduates. Modern engineering professionals must be capable of working with large volumes of information, adapting to rapidly changing technological environments, and engaging in lifelong learning. Critical thinking enables students to critically assess information sources, distinguish reliable data from misinformation, and apply knowledge effectively in diverse contexts. Therefore, the integration of critical thinking into engineering education is essential for preparing graduates who can contribute to technological innovation and sustainable development.

Despite the recognized importance of critical thinking, many educational institutions continue to face challenges in effectively incorporating it into engineering programs. These challenges include limited instructional resources, insufficient teacher preparation, traditional assessment practices, and a lack of systematic methodologies for competency development. Consequently, there is a growing need for pedagogical frameworks that support the integration of critical thinking into engineering education and facilitate the development of professional competencies.

This article examines the role of critical thinking in the development of engineering students' competencies and proposes a methodological approach for its effective integration into the educational process. The study aims to identify pedagogical strategies, instructional methods, and assessment techniques that contribute to the enhancement of critical thinking skills and professional competencies among engineering students. By exploring contemporary educational practices and theoretical perspectives, the article seeks to provide recommendations for improving the quality and effectiveness of engineering education in the modern era.

**Main Part.** The transformation of modern engineering education is closely associated with the growing demand for highly qualified specialists capable of addressing complex technical, social, and environmental challenges. Engineering graduates are expected not only to possess a solid foundation of technical knowledge but also to demonstrate analytical reasoning, creativity, adaptability, communication skills, and the ability to make responsible decisions in uncertain situations. In this regard, the concept of competency-based education has become one of the central paradigms in higher education, emphasizing the development of integrated professional competencies rather than the mere acquisition of theoretical knowledge. Critical thinking occupies a central position within this paradigm because it enables students to effectively apply their knowledge, evaluate information, and solve real-world problems.

The concept of critical thinking has been extensively explored by educational scholars and researchers. According to Richard Paul and Linda Elder, critical thinking is "the art of analyzing and evaluating thinking with a view to improving it" (Paul & Elder, 2014). This definition highlights the reflective and self-regulatory nature of critical thinking, emphasizing the importance of continuously assessing one's own reasoning processes. In engineering education, such reflective thinking allows

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students to identify weaknesses in their problem-solving strategies and improve the quality of their decisions. Similarly, Robert Ennis (2011) defines critical thinking as reasonable and reflective thinking focused on deciding what to believe or do. This perspective is particularly relevant to engineering practice, where professionals are often required to make decisions based on incomplete information, competing alternatives, and potential risks.

Engineering education has traditionally relied on lecture-based instruction, where students are primarily passive recipients of information. Although this approach may be effective for transmitting theoretical knowledge, it often fails to foster higher-order cognitive skills necessary for professional practice. Contemporary educational research suggests that students develop critical thinking more effectively when they actively engage in problem-solving, discussion, collaboration, and reflection. For this reason, many universities have adopted learner-centered approaches that encourage students to become active participants in the educational process. Such approaches create opportunities for students to analyze engineering problems from multiple perspectives, evaluate evidence, and construct well-reasoned solutions.

One of the most effective methods for developing critical thinking competencies in engineering education is problem-based learning (PBL). This approach places students in situations where they must investigate and solve authentic engineering problems. Rather than receiving ready-made solutions, students are encouraged to identify relevant information, formulate hypotheses, conduct research, and justify their conclusions. Through this process, learners develop not only technical knowledge but also analytical reasoning, teamwork, and communication skills. Research conducted by Prince and Felder (2006) demonstrates that problem-based learning significantly improves students' ability to apply knowledge in practical situations and enhances critical thinking performance. Furthermore, PBL helps bridge the gap between theoretical learning and professional practice by exposing students to realistic engineering challenges.

Project-based learning represents another valuable strategy for competency development. In engineering disciplines, projects provide students with opportunities to integrate knowledge from multiple subject areas while addressing practical problems. Students are required to plan activities, allocate resources, evaluate constraints, and assess the effectiveness of proposed solutions. Such experiences contribute to the development of systems thinking and decision-making competencies. As noted by Thomas (2000), project-based learning encourages deeper understanding by engaging students in complex tasks that require sustained inquiry and critical reflection. Engineering projects also promote innovation because students must often generate original ideas and adapt their solutions to changing conditions.

The integration of case studies into engineering curricula further supports the development of critical thinking skills. Case-based instruction exposes students to real-world engineering successes and failures, enabling them to examine the factors that influence decision-making processes. Through the analysis of case studies, students learn to evaluate evidence, identify assumptions, and consider the ethical implications of engineering actions. This method is particularly valuable in preparing future engineers to address professional responsibilities and societal expectations. Engineering failures such as bridge collapses, industrial accidents, or technological malfunctions provide important learning opportunities that encourage students to critically assess design choices and risk management strategies.

Collaborative learning also plays a significant role in fostering critical thinking competencies. Engineering practice frequently involves teamwork and interdisciplinary cooperation; therefore, educational environments should reflect these professional realities. Collaborative learning activities encourage students to exchange ideas, challenge assumptions, and defend their viewpoints using

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logical arguments. According to Vygotsky's social constructivist theory, knowledge is constructed through social interaction and dialogue. When engineering students work together to solve problems, they benefit from diverse perspectives and develop stronger analytical skills. Moreover, collaboration enhances communication competencies, which are essential for effective engineering practice.

The increasing availability of digital technologies has created new opportunities for the development of critical thinking in engineering education. Simulation software, virtual laboratories, artificial intelligence tools, and online learning platforms enable students to explore complex engineering systems in interactive ways. Digital technologies provide access to vast amounts of information, but they also require students to critically evaluate the credibility and relevance of data sources. Consequently, information literacy has become an important component of engineering competencies. Students must learn how to distinguish reliable information from inaccurate or misleading content and apply evidence-based reasoning in their academic and professional activities.

The assessment of critical thinking competencies remains one of the most challenging aspects of engineering education. Traditional examinations often focus on memorization and procedural knowledge rather than higher-order cognitive skills. Therefore, educators increasingly employ alternative assessment methods such as portfolios, reflective journals, project reports, presentations, and performance-based evaluations. These assessment tools provide a more comprehensive picture of students' ability to analyze information, justify decisions, and apply knowledge in authentic contexts. Effective assessment should not only measure learning outcomes but also encourage continuous reflection and self-improvement.

Another important consideration is the role of instructors in promoting critical thinking. Faculty members must create learning environments that encourage inquiry, discussion, and intellectual curiosity. Instead of simply delivering information, instructors should act as facilitators who guide students through the process of questioning assumptions, evaluating evidence, and constructing knowledge. Brookfield (2012) argues that critical thinking develops most effectively when learners are exposed to diverse viewpoints and are encouraged to challenge their own beliefs. Therefore, engineering educators should design activities that stimulate debate, analysis, and reflection.

The development of critical thinking competencies is also closely linked to professional ethics. Engineers make decisions that can have significant consequences for public safety, environmental sustainability, and economic development. Consequently, engineering education must prepare students to evaluate not only technical factors but also ethical considerations. Critical thinking enables future engineers to assess the broader impact of their actions, recognize ethical dilemmas, and make responsible decisions. Integrating ethics into engineering curricula contributes to the formation of socially responsible professionals capable of balancing technological innovation with societal needs.

In the context of globalization and rapid technological change, lifelong learning has become an essential competency for engineering professionals. Critical thinking supports lifelong learning by enabling individuals to continuously evaluate new information, adapt to changing circumstances, and acquire new knowledge throughout their careers. Engineers who possess strong critical thinking skills are better equipped to respond to emerging challenges and contribute to technological advancement. Therefore, the cultivation of critical thinking should be viewed not merely as an educational objective but as a fundamental requirement for professional success in the twenty-first century.

Overall, the effective development of engineering students' competencies requires a systematic pedagogical approach that integrates critical thinking across all aspects of the educational process. Problem-based learning, project-based learning, case studies, collaborative learning, digital technologies, and authentic assessment methods collectively contribute to the formation of analytical, professional, and interpersonal competencies. By embedding critical thinking into engineering

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curricula, higher education institutions can prepare graduates who are capable of addressing complex problems, generating innovative solutions, and making informed decisions in a rapidly evolving world.

**Conclusion.** In conclusion, the development of engineering students' competencies through critical thinking has become a fundamental objective of contemporary higher education. The increasing complexity of technological systems, rapid industrial transformation, and the growing demand for innovative solutions require engineering graduates to possess not only technical expertise but also strong analytical and decision-making abilities. Critical thinking serves as a foundation for these competencies by enabling students to evaluate information objectively, solve complex problems, and make well-reasoned judgments in professional contexts.

The study has demonstrated that the integration of critical thinking into engineering education can be effectively achieved through learner-centered pedagogical approaches, including problem-based learning, project-based learning, case study analysis, collaborative learning, and the use of digital technologies. These methods encourage active engagement, independent inquiry, and reflective thinking, thereby contributing to the development of both technical and transferable competencies. In addition, authentic assessment strategies and constructive feedback play a vital role in supporting students' cognitive growth and professional preparedness.

The findings suggest that critical thinking should not be treated as a separate educational component but rather as an integral element embedded throughout the engineering curriculum. A systematic and competency-oriented approach to teaching and learning can significantly enhance students' ability to adapt to changing professional environments, engage in lifelong learning, and contribute to technological innovation and sustainable development.

Therefore, higher education institutions must continue to strengthen instructional practices that foster critical thinking and competency development. By doing so, they will prepare future engineers who are capable of addressing complex challenges, generating innovative solutions, and making responsible decisions that positively impact society and the global engineering profession.

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