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Developing Technological Creativity Competence of Future Engineers in The Education Cluster Environment

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Abstract:

This article examines the methodological foundations for developing the technological creativity competence of future engineers in an education cluster environment. The central argument is that technological creativity in engineering education cannot be reduced to occasional inventive tasks or isolated project work. It should be cultivated as an integrated competence combining creative thinking, engineering design, interdisciplinary cooperation, technological literacy, reflective judgment, and the ability to solve real-world problems in collaboration with external stakeholders. In this article, the education cluster environment is understood as a pedagogical ecosystem that unites higher education institutions, schools, research units, enterprises, innovation platforms, and professional communities around shared educational and technological tasks.

Keywords: Technological Creativity Competence, Future Engineers, Engineering Education, Education Cluster Environment, Competence-Based Education

Introduction

The preparation of future engineers is increasingly discussed not only in terms of technical knowledge acquisition but also in relation to broader competences required by contemporary production, innovation, and social transformation. Recent engineering education research indicates that future engineers need more than strong disciplinary training. They are expected to operate in complex systems, work across disciplinary boundaries, communicate with diverse stakeholders, and generate original yet feasible solutions under real constraints. In competence-oriented discussions, creativity is not treated as an optional personal trait but as a necessary component of engineering professionalism. The CDIO Standards 3.0 define engineering education through learning outcomes that combine disciplinary knowledge with personal and interpersonal skills, as well as product, process, system, and service building skills. These standards explicitly include engineering reasoning, problem-solving, systems thinking, creative thinking, teamwork, and stakeholder-validated outcomes, which means that creativity is already embedded in internationally recognized models of engineering reform [1]. A recent systematic review on Engineering Education 5.0 reaches a similar conclusion, arguing that future engineering education must be realigned around competence profiles rather than narrow content transmission [2]. Interdisciplinary engineering education research further shows that modern engineering challenges demand educational strategies capable of integrating technical, social, and reflective dimensions of competence [3].

Materials and Method

A methodological discussion of technological creativity competence should begin with its internal structure. In traditional curricula, creativity is often interpreted narrowly, either as a talent belonging to a small group of gifted students or as an occasional by-product of design assignments. Such an approach is insufficient[4]. Engineering education research demonstrates that creativity can be developed deliberately when it is connected to cognitive, metacognitive, and collaborative pedagogical practices. Morin, Robert, and Gabora describe a creativity course for engineering students built on a cognitive and metacognitive approach and report that students' scores in fluidity, flexibility, originality, and usefulness increased after the intervention [5]. This is methodologically important because it shows that creativity in engineering is trainable, measurable, and pedagogically designable. At the same time, creativity in engineering should not be separated from technological competence. A technically imaginative but technologically ungrounded idea remains pedagogically incomplete, while a purely reproductive technical performance does not prepare students for innovation. Therefore, technological creativity competence should be understood as an integrated result of knowledge, imagination, technical reasoning, design action, and critical evaluation. Such a definition has direct implications for curriculum design: if competence is integrated, the learning environment must also be integrated [6].

Results and Discussion

The education cluster environment provides that integrated context more effectively than isolated classroom instruction. In analytical terms, an education cluster is not merely a formal partnership or administrative network. It is a coordinated pedagogical environment in which different institutions contribute complementary resources to the training of future engineers. The university contributes theoretical and methodological grounding; enterprises contribute technological tasks, professional standards, and production realities; research laboratories contribute experimental culture; schools and pre-university institutions contribute continuity of preparation; innovation centers and start-up spaces contribute entrepreneurial and design-oriented practices. The methodological value of the cluster lies in its ability to create continuity between learning and application. Research on higher education–industry collaboration in engineering confirms that such collaboration supports student transitions to work life, strengthens curricula, improves motivation, and creates professional relevance, although it also requires stable organizational conditions. The same review identifies six major factors of successful collaboration—clarity, communication, commonality, commitment, continuity, and confidence—which are especially useful for designing cluster-based educational practice [7]. From a pedagogical viewpoint, these factors can be transformed into methodological principles: clarity of competence goals, sustained communication among stakeholders, a shared project culture, institutional commitment, continuity of collaboration, and mutual trust in assessment and outcomes.

A second essential condition is competence-based curriculum integration. One of the main weaknesses of many engineering programs is fragmentation: disciplinary courses are taught separately, practical tasks are episodic, and creative or project-related experiences are added as optional supplements. The CDIO Standards reject this logic. They explicitly define an integrated curriculum as one in which disciplinary knowledge is interwoven with personal, interpersonal, and engineering-building skills, and they insist that these skills should not be treated as an addition to an already full curriculum but as an integral part of it [8]. This principle is directly applicable to technological creativity competence. If a university expects students to become technologically creative, it cannot confine that task to a single course in innovation or project management. The competence must be distributed across the curriculum: introductory engineering courses should stimulate hands-on and creative engagement; disciplinary modules should include open-ended technical tasks; laboratory work should include design variation and experimentation; and advanced courses should culminate in complex design-implement experiences. Pacher and colleagues likewise argue that competence-based engineering education requires systematic realignment of professional education initiatives and provides methods and tools for such realignment [9]. Therefore, the methodology of cluster-based creativity development begins with curriculum architecture, not with extracurricular activity alone.

A third condition concerns interdisciplinarity. Technological creativity is rarely generated within a single disciplinary logic. Contemporary engineering problems involve technical performance, sustainability, digitalization, ergonomics, economics, communication, and social acceptability. Ming, van der Veen, and MacLeod show that interdisciplinary engineering education is gaining traction precisely because globalized systems exceed traditional disciplinary boundaries. Their study proposes six interdisciplinary engineering education competency categories and identifies three perspectives through which interdisciplinarity is understood: social-holistic, technical problem-solving, and reflective pragmatic [10]. These findings are methodologically significant for the education cluster environment. A cluster does not simply bring institutions together; it also brings epistemologies together[11]. Future engineers should therefore be trained to move between specialized technical reasoning and broader socio-technical reflection. In practical terms, this means that technological creativity tasks should involve not only engineering functionality but also users, contexts, sustainability constraints, communication with non-engineers, and reflective evaluation of alternative solutions. When students learn to see engineering problems as socio-technical systems rather than isolated technical puzzles, creativity acquires a more productive and professionally relevant character[12].

A fourth methodological pillar is challenge-based learning. Doulougeri, Vermunt, Bombaerts, and Bots describe challenge-based learning as a pedagogical approach increasingly adopted in engineering education and show that its implementations are centered on real-world challenges, multidisciplinary participation, stakeholder perspectives, and the fostering of innovation and creativity [13]. This is highly relevant for developing technological creativity competence because authentic challenges activate the exact cognitive and practical processes that such competence requires: problem framing, idea generation, feasibility analysis, prototyping, iteration, teamwork, and public justification of solutions[14]. In a cluster environment, challenge-based learning becomes even more powerful because the challenges can be derived from partner enterprises, local communities, research laboratories, or educational institutions within the cluster itself. As a result, students do not merely simulate professional activity; they enter a pedagogically supported version of genuine engineering practice[15].

Conclusion

The development of technological creativity competence among future engineers requires a methodological shift from fragmented instruction to integrated educational design. Creativity in engineering should not be treated as a marginal supplement to technical training. It is a core professional capacity that connects engineering knowledge with design imagination, systems thinking, experimentation, feasibility analysis, and socially responsive problem-solving. The reviewed sources consistently indicate that competence-based curricula, interdisciplinary learning, design-implement experiences, stakeholder-validated outcomes, and authentic challenge-centered pedagogy provide the most productive conditions for such development.

References

[1] CDIO Initiative, CDIO Standards 3.0, 2022.
[2] C. Pacher et al., “Engineering Education 5.0,” Production & Manufacturing Research, 2024.
[3] X. Ming et al., “Interdisciplinary Engineering Competencies,” European Journal of Engineering Education, 2025.
[4] A. Vuoriainen et al., “Six C’s Collaboration,” European Journal of Engineering Education, 2025.
[5] K. Doulougeri et al., “Challenge-based Learning,” Journal of Engineering Education, 2024.
[6] S. Morin et al., “Engineering Creativity Training,” Thinking Skills and Creativity, 2018.
[7] J. Biggs, Teaching for Quality Learning, 2011.
[8] L. Darling-Hammond, Powerful Learning, 2008.
[9] OECD, Education 2030, 2019.
[10] ABET, Engineering Criteria, 2022.
[11] P. Prince and R. Felder, “Inductive Teaching,” JEE, 2006.
[12] D. Kolb, Experiential Learning, 1984.
[13] UNESCO, Engineering Education Report, 2021.
[14] M. Fullan, Educational Change, 2007.
[15] World Economic Forum, Future of Jobs, 2023.