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Article

Innovative Methods for Strengthening Technological Creativity of Future Engineers in Cluster-Based Education

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Abstract: This article analyzes innovative methods for strengthening the technological creativity of future engineers in cluster-based education. The article proceeds from the premise that technological creativity is a professionally significant competence combining originality, engineering feasibility, interdisciplinary reasoning, experimentation, collaboration, and reflective decision-making. In cluster-based education, universities, schools, laboratories, industrial enterprises, and innovation-oriented partners form a shared educational environment in which students engage with authentic technical problems and receive feedback from multiple stakeholders.

Keywords: technological creativity, future engineers, cluster-based education, engineering education, innovative methods.

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Introduction

The contemporary transformation of engineering education has made creativity a central pedagogical issue rather than a marginal personal characteristic. Engineering graduates are now expected to operate in technologically dynamic, interdisciplinary, and socially complex environments, where success depends not only on technical precision but also on the ability to generate original, workable, and context-sensitive solutions[1]. The CDIO Standards 3.0 place engineering learning outcomes within a framework that combines disciplinary foundations with personal, interpersonal, and product-process-system building skills, while recent competence-based reviews in engineering education argue that future-oriented programs must move beyond narrow knowledge transmission toward integrated competence formation [2]. From this perspective, technological creativity is not a decorative addition to engineering training. It is one of the capacities through which future engineers turn knowledge into innovation, design, adaptation, and responsible implementation.

Materials and Methods

Within this discussion, cluster-based education offers a particularly productive setting. In the present article, cluster-based education is understood as an organized pedagogical environment in which universities cooperate with schools, laboratories, enterprises, and innovation platforms around shared educational and technological tasks [3]. This interpretation is consistent with research showing that engineering education benefits from closer links with external stakeholders, especially when collaboration supports student transition to work life, curricular relevance, and authentic professional experience [4]. The purpose of this article is to identify innovative methods that can strengthen the technological creativity of future engineers in such cluster environments. The core argument is that these methods are effective only when they operate as a connected pedagogical system rather than as isolated innovations added to a conventional curriculum.

Results and Discussion

A first innovative method is integrated design-build learning, especially in curricula shaped by the CDIO approach. Traditional engineering instruction often separates theory from action: students first accumulate concepts and only later apply them in limited project formats[5]. This separation weakens creativity because it postpones the moment when students must transform abstract knowledge into technical decisions. CDIO-oriented learning offers a different logic. It organizes education around conceiving, designing, implementing, and operating products, processes, or systems in realistic contexts, and it explicitly links learning outcomes to stakeholder expectations and authentic engineering practice [6]. As an innovative method for strengthening technological creativity, integrated design-build learning compels students to move from idea generation to prototyping and evaluation. Creativity here is not treated as free imagination; it becomes disciplined invention under material, temporal, and functional constraints. In cluster-based education, this method gains additional force because external partners can supply real technical challenges, testing environments, and design feedback, thereby giving students repeated opportunities to develop creative engineering judgment [7].

A second innovative method is challenge-based learning, which has become increasingly influential in engineering pedagogy. The recent systematic literature review on challenge-based learning in engineering education shows that this approach commonly involves authentic challenges, multidisciplinary participation, stakeholder perspectives, and innovation-oriented outcomes [8]. Its pedagogical value lies in the fact that students are not simply asked to solve textbook problems; they must define and reframe problems, negotiate uncertainty, identify constraints, generate alternatives, and iteratively improve their solutions. In cluster-based education, challenge-based learning is especially suitable because the “challenge” can emerge from actual partner needs: an industrial process bottleneck, a local infrastructure issue, an educational technology problem, or a sustainability-oriented engineering task[9]. This method strengthens technological creativity because it trains students to see engineering not as procedural compliance, but as purposeful design activity in conditions of complexity. The novelty of the method lies not merely in using projects, but in organizing learning around socially and technologically meaningful problems that resist one-step solutions [10].

A third innovative method is interdisciplinary project studios. Research on interdisciplinary engineering education shows that competence in this area includes several categories and can be viewed through social-holistic, technical problem-solving, and reflective-pragmatic perspectives [11]. This matters because technological creativity rarely grows inside a single disciplinary frame[12]. Contemporary engineering tasks are shaped simultaneously by technical performance, digital systems, user needs, environmental requirements, economic feasibility, and communication demands. Interdisciplinary project studios respond to this reality by bringing students from different engineering specializations, and sometimes from non-engineering fields, into a shared design space[13]. In a cluster environment, such studios may include contributions from industry engineers, teachers, school innovators, or research staff. Their innovative character lies in the deliberate collision of perspectives. Students learn to strengthen creativity not by producing more ideas in isolation, but by reworking ideas through encounters with different forms of expertise. Such collaboration helps them understand that originality in engineering becomes valuable only when it is technically sound, contextually responsive, and communicatively defensible [14].

A fourth innovative method is structured co-creation with industry and external stakeholders. Collaboration with external organizations is often mentioned in engineering education, but it becomes pedagogically innovative only when it is designed as a shared learning process rather than as occasional consultation. The systematic review on higher education–industry collaboration in engineering education identifies six recurring conditions of successful cooperation: clarity, communication, commonality, commitment, continuity, and confidence [15]. Translated into pedagogical terms, these conditions allow educators to turn stakeholder participation into a method for creativity formation. Students can work with real constraints, negotiate expectations, justify design choices, and revise solutions in light of professional feedback.

Conclusion

The strengthening of technological creativity among future engineers requires more than a general call for innovation in higher education. It requires concrete pedagogical methods that repeatedly place students in situations of open-ended design, interdisciplinary negotiation, iterative improvement, and accountable invention. The scholarly sources considered here show that competence-based curriculum logic, CDIO-oriented design-build experience, challenge-based learning, interdisciplinary competence development, industry-linked collaboration, and explicit creativity pedagogy all contribute to this goal when they are methodologically integrated.

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