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The Role of Cooperative Learning in Undergraduate Engineering Education: A Better Alternative to Teacher-Centered Learning

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Abstract: *This comprehensive analysis examines the effectiveness of cooperative learning (CL) in undergraduate engineering education, contrasting it with traditional teacher-centered methods. The study finds that CL enhances academic performance and develops essential skills such as critical thinking, teamwork, and communication. Unlike passive teacher-centered methods, CL promotes active participation and collaborative problem-solving, better aligning educational outcomes with the demands of the engineering profession. The article highlights the limitations of teacher-centered learning, which often fails to foster deep understanding or student engagement. CL, involving students in diverse, role-defined groups, helps them connect theory to practice, particularly benefiting first-year students transitioning into collaborative environments. However, challenges to implementing CL include student resistance, higher instructor workload, and the need for effective group management. The study stresses the importance of faculty training, discipline-specific resources, and structured support to address these obstacles. Ultimately, the article advocates for a shift toward CL in engineering education, emphasizing its potential to prepare students for collaborative, dynamic engineering roles in a technologically advanced world.*

INTRODUCTION

Cooperative learning (CL) is a student-centered instructional approach where small groups work together to achieve common goals (Metzler & Colquitt, 2021; Richards & Rodgers, 2001). It promotes socialization, learning, and higher-order thinking across various subjects and educational levels (Gillies, 2016; Lin, 2006) . Key elements of CL include positive interdependence, face-to-face interaction, and individual accountability (Richards & Rodgers, 2001). CL differs from collaborative learning, a personal philosophy based on consensus-building.

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Research shows CL enhances academic achievement, social skills, and cross-ethnic cooperation (Gillies, 2016; Lin, 2006). It also improves relationships among diverse students (Lin, 2006). Teachers play a crucial role in implementing CL effectively by structuring tasks and developing students' thinking (Gillies, 2016). CL is closely related to, but distinct from, collaborative learning and interaction in language classrooms (Oxford, 1997).

Cooperative learning (CL) in engineering education is increasingly recognized as crucial for developing teamwork, communication, and problem-solving skills essential in industry (Duwart & Canale, 1997; Mourtos, 1994). It helps bridge the gap between theory and application, preparing students for global competition (Mohankrishnan & Yost, 1998). CL encourages active involvement, interdependence, and higher-order thinking skills among students (Mayrose & Kukulka, 2008; Smith & Goldstein, 1982). Integrating CL principles into engineering design processes can enhance teamwork knowledge, effectiveness, and performance (Baligar et al., 2021). CL is particularly valuable for first-year students who may lack prior experience in intensive problem-solving and team-based work (Baligar et al., 2021). As an alternative to traditional lecture-based teaching, CL can optimize engineering education outcomes, fostering diverse skills beyond technical knowledge (Desai & kulkarni, 2016). Despite its potential, discipline-specific resources for implementing CL in engineering education remain relatively scarce (Ledlow, 2002).

Recent research highlights the limitations of teacher-centered learning and advocates for more student-centered learning. While teacher-centered methods can efficiently deliver information, they may not promote deep learning or engagement (Levitt & Grubaugh, 2023). Student-centered learning fosters critical thinking, active participation, and real-world application of concepts (Ghafar, 2023; Mascolo, 2009). However, implementing these methods presents challenges for educators, including resource intensity, adapting to specific contexts, and translating theory into practice (Aslan & Reigeluth, 2015; Sadler, 2012). Studies have shown that learner-centered learning can increase student participation by up to 20% compared to traditional methods (Markina & Garcia Mollá, 2022). To overcome challenges, educators need support through professional development, collaboration, and self-reflection (Levitt & Grubaugh, 2023). The shift towards student-centered learning aligns with current learning theories and emphasizes the teacher's role as a facilitator rather than a knowledge dispenser (Chaudhary, 2024; Smart et al., 2012).

The main objective of this study is to explore the role of CL as an alternative learning approach that is more effective than teacher-centered methods in undergraduate engineering education. This study aims to analyze how CL can increase student active engagement, facilitate collaborative learning, and deepen understanding of complex technical concepts. In addition, this study will identify the potential of CL in building interpersonal and teamwork skills that are essential in the professional world. The significance of this study lies in its ability to provide empirical evidence that supports the implementation of CL in engineering education curricula, as well as its contribution to improving the quality of learning that is more applicable and relevant to the demands of modern industry. With the expected results, this study can be a foundation for pedagogical changes that support the development of engineering students' competencies in an increasingly collaborative and technology-based global context.

LIMITATIONS OF TEACHER-CENTERED LEARNING

While efficient for delivering information, teacher-centred learning often fails to promote deep learning, engagement, and critical thinking (Levitt & Grubaugh, 2023). These methods can leave students with learning disabilities minimally benefiting from instruction (Otukile-

Mongwaketse, 2018) and negatively affect overall learning achievement (Mackatiani et al., 2018). Despite implementing competency-based learning, teacher-centered paradigms still prevail in many educational settings due to constraints such as crowded classrooms, exam requirements, and time restrictions (Baghoussi, 2021) . This approach emphasizes the teacher's role as the primary source of information and authority figure (Ghafar, 2023) , which can hinder the development of critical thinking, research-mindedness, and positive attitudes towards change in students (Sweeney, 1986). To address these limitations, educators are encouraged to incorporate more student-centered learning that fosters active learning, self-direction, and engagement while providing professional development and support for teachers (Levitt & Grubaugh, 2023).

Traditional teacher-centered learning, characterized by lectures and direct instruction, has long been the cornerstone of engineering education. However, these methods have faced increasing criticism for failing to prepare students for real-world challenges adequately. In engineering, students often experience difficulty applying theoretical knowledge to practical situations and struggle with collaborative problem-solving, skills vital for their professional growth (Litzinger et al., 2011). Moreover, such passive learning environments may not foster a deep conceptual understanding of the technical and professional skills required in the modern engineering workplace. The rigid structure of these methods may also limit students' ability to engage in reflective practices or function effectively in team-based settings (Huggard et al., 2014).

Teacher-centered methods, characterized by high teacher control, can constrain cognitive engagement and intrinsic motivation (Hanrahan, 1998). The Bridge21 model, emphasizing team-based and technology-mediated learning, has positively impacted students' intrinsic motivation (Lawlor et al., 2016). Self-determination theory highlights the importance of supporting students' basic psychological needs for autonomy, competence, and relatedness to foster intrinsic motivation (Ryan & Deci, 2020) . Student-centered instruction, involving active learning strategies, can enhance intrinsic motivation by providing more challenge, choice, and control over learning activities (Phillips, 2006) . However, technology use alone does not necessarily improve intrinsic motivation; effective instructional design is crucial for linking student-centered and technology-based learning.

While efficient for delivering information, teacher-centred learning is often criticized for failing to foster deep learning, critical thinking, and engagement, especially among students with learning disabilities. These methods are still prevalent in many educational settings due to factors like crowded classrooms and time constraints, and they focus on the teacher as the primary source of knowledge, limiting students' development of essential skills such as critical thinking, problem-solving, and collaboration. In engineering education, this approach often leaves students struggling to apply theoretical knowledge to real-world situations and work effectively in teams, which are vital professional skills. Moreover, such passive learning environments can hinder cognitive engagement and intrinsic motivation. To address these issues, student-centered learning, including active learning and team-based methods, is recommended, as they promote self-direction, engagement, and motivation, provided they are supported by effective instructional design and professional development for educators.

BENEFITS OF COOPERATIVE LEARNING

Cooperative learning (CL) provides a viable alternative to the limitations of teacher-centered learning. This student-centered model emphasizes collaboration, shared leadership, and active problem-solving. Working in small groups, students engage more deeply with course material, develop critical thinking skills, and practice real-world teamwork. Research has shown that CL strategies, such as project-based learning and peer collaboration, significantly improve students' attitudes toward group work and overall academic performance (Huggard et al., 2014). Moreover, by incorporating shared leadership models, CL helps students build leadership skills while reinforcing accountability within group tasks (Galli & Luechtefeld, 2009).

For example, a study integrating CL in an introductory engineering laboratory module revealed that students' engagement and reflection on their learning were enhanced when they worked in collaborative teams. Students could apply theoretical concepts, develop a more positive attitude toward group work, and be better prepared for professional practice (Huggard et al., 2014) . Additionally, shared leadership in engineering courses has increased student participation, fostered decision-making skills, and promoted a deeper understanding of the content (Galli & Luechtefeld, 2009).

Cooperative learning (CL) has enhanced students' motivation and satisfaction in various educational contexts. Studies have demonstrated that CL can improve intrinsic motivation, self-efficacy, and learning goal orientation in algebra and geometry (Nichols, 1996; Nichols & Miller, 1994). CL promotes a sense of shared achievement and belonging, which contributes to increased student engagement and satisfaction (Brecke, 2007; DÖRNYEI, 1997) . Research has also indicated that CL can reduce communication apprehension and improve expectancy fulfilment in group activities (Dobos, 1996). In foreign language learning, CL techniques have been found to significantly impact learners' motivation across various subscales (Fakhri Alamdari & Ghani, 2022) . Furthermore, implementing learning communities in STEM education has positively affected students' attitudes, learning experiences, and intrinsic motivation (Freeman et al., 2008). Computer-mediated communication in CL contexts can enhance language learners' motivation, confidence, and satisfaction(Wu et al., 2012).

IMPLEMENTING COOPERATIVE LEARNING IN ENGINEERING EDUCATION

The successful implementation of cooperative learning (CL) in undergraduate engineering education requires careful planning and instructor support. Faculty must design curricula incorporating CL principles, such as project-based assignments, peer review, and collaborative problem-solving activities. Instructors should provide structured opportunities for students to engage in meaningful group work, where they are held accountable for their contributions and the group's overall success(Chitti et al., 2020). Furthermore, integrating outcome-based learning and reflective practices into the curriculum will help students develop both the technical skills and the professional dispositions necessary for the engineering profession (Chitti et al., 2020).

Research highlights the importance of training and support for lecturers to effectively implement CL and technology integration in higher education. Studies emphasize the need for developing lecturers' technological pedagogical content knowledge (TPACK) to enhance their ability to use collaborative tools and design effective CL activities (Tynan et al., 2008) . Personalized support and training programs have improved lecturers' digital literacy, content creation skills, and ability to address diverse student needs in blended learning environments (Ali et al., 2024). Training in team skills can significantly enhance student group performance in CL settings (Prichard et al., 2006) . Additionally, supporting lecturers through transitioning from traditional lectures to interactive group work is crucial for successfully implementing CL (Stewart & McCormack, 1997) . Overall, these studies underscore the critical role of lecturer training and support in ensuring the effective use of technology and CL strategies in higher education (Tynan et al., 2008).

A shift toward CL also necessitates faculty support students in acquiring key interpersonal skills, such as communication, conflict resolution, and self-regulation. These skills are vital for successful collaboration in real-world engineering projects, where interdisciplinary teamwork and effective communication are essential (Rajan et al., 2019). By fostering a learning environment that emphasizes collaboration and accountability, engineering programs can better prepare students for the collaborative nature of the profession.

Key principles and practices of cooperative learning

Cooperative learning (CL) is a structured approach that encourages students to work together towards shared goals, promoting cognitive and interpersonal skills development. The core principles of CL include positive interdependence, individual accountability, face-to-face interaction, social skills development, and group processing (Chitti et al., 2020; Huggard et al., 2014; Rajan et al., 2019).

- Effective implementation of CL in engineering courses involves the following practices:
- Engaging, Real-World Projects: Designing projects that require students to apply theoretical knowledge to solve complex, real-world problems fosters a deeper understanding of the material and enhances problem-solving skills.
- Structured Group Work: Groups should be carefully designed to ensure diverse skill sets and perspectives, encouraging collaboration and accountability.
- Peer Teaching and Feedback: Encouraging students to explain concepts to their peers fosters mastery of the material and the development of communication skills.
- Reflection and Self-Assessment: Regular opportunities for students to reflect on their learning process and evaluate their contributions promote self-regulation and continuous improvement.

These practices provide a comprehensive framework for integrating CL into engineering education. They improve students' academic performance and prepare them for the collaborative, problem-solving demands of the engineering profession. CL equips students with the skills needed to succeed in a rapidly changing and increasingly interconnected world by fostering cognitive and interpersonal development.

- Advantages of cooperative learning (CL) in engineering education
- Cooperative learning (CL) offers several distinct advantages over traditional teacher-centered methods in engineering education:
- Enhanced Critical Thinking: Active, collaborative learning fosters deeper engagement with course material and encourages students to think critically and creatively (Galli & Luechtefeld, 2009; Huggard et al., 2014).
- Development of Professional Skills: Through structured group work, students develop key professional skills, including teamwork, leadership, and communication, which are crucial for success in the engineering field (Galli & Luechtefeld, 2009).
- Deeper Understanding: CL requires students to articulate their understanding to peers, engage in discussions, and critically evaluate different viewpoints, leading to a more profound understanding of course content (Litzinger et al., 2011).
- Inclusive Learning Environment: By involving all students in group activities and fostering a sense of shared responsibility, CL promotes inclusivity and ensures that all voices are heard.

Cooperative learning (CL) in engineering education offers distinct advantages beyond traditional teacher-centered methods, preparing students for modern engineering practice's collaborative and dynamic nature. It enhances critical thinking by fostering profound engagement

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with course material and encouraging creative problem-solving. Through structured group work, students develop essential professional skills such as teamwork, leadership, and communication, which are crucial for success in the engineering field. The peer mentoring aspect of CL promotes confidence, inclusivity, and a sense of community as students support one another, share knowledge, and build mutual understanding. This approach also facilitates the transferability of skills, enabling students to adapt to real-world work environments where interdisciplinary collaboration and effective communication are key. Moreover, CL boosts intrinsic motivation and engagement, as students share accountability with their peers and celebrate collective achievements, fostering a positive attitude toward learning. By integrating these cognitive and professional benefits, CL equips students with the tools necessary to excel in their academic and professional endeavours.

Challenges and considerations

Despite its potential benefits, the implementation of CL in engineering education comes with specific challenges:

- Student Resistance: Engineering students may initially resist group-based learning, preferring the more familiar lecture format. Overcoming this resistance requires careful preparation and orientation (Huggard et al., 2014).
- Instructor Effort: The design and management of CL activities require significant time and effort from instructors, particularly in large classes.
- Group Dynamics: Managing group work effectively can be challenging, especially in large classrooms. Ensuring that each student is accountable for their contributions while maintaining a collaborative environment requires careful planning.
- Development of Interpersonal Skills: Students must be provided with guidance and support to develop the necessary interpersonal skills for successful teamwork, including conflict resolution, communication, and self-regulation.

Addressing these challenges requires a strategic and well-planned approach to ensure the successful implementation of CL in engineering education. Instructors play a pivotal role in mitigating student resistance by clearly communicating the benefits of CL and gradually integrating it into the curriculum to allow students to adapt to this new approach. Professional development programs can provide instructors with the tools and techniques to design, facilitate, and manage CL activities effectively, even in large classrooms. To address issues related to group dynamics, implementing structured mechanisms such as role assignments, regular progress check-ins, and peer evaluations can help maintain accountability and ensure equitable participation. Additionally, incorporating specific training sessions focused on interpersonal skills, such as effective communication and conflict resolution, can equip students with the tools needed for successful collaboration. By addressing these considerations proactively, educators can create a more supportive environment that maximizes the benefits of CL while minimizing its challenges.

CONCLUSION

Based on the comprehensive analysis of the Role of Cooperative Learning (CL) in Undergraduate Engineering: A Better Alternative to Teacher-Centered Learning, this research underscores the transformative potential of CL in undergraduate engineering education, presenting it as a superior alternative to traditional teacher-centered learning. CL enhances academic performance by fostering critical thinking and deeper engagement with course material and equips students with essential professional skills such as teamwork, leadership, and communication. These skills are increasingly vital in modern engineering, where interdisciplinary collaboration and effective problem-solving are paramount.

The study highlights that while teacher-centered methods efficiently deliver information, they often fall short in promoting deep learning and engagement, leaving students ill-prepared for real-world challenges. In contrast, CL offers a holistic educational experience by integrating cognitive and interpersonal development, aligning more closely with the demands of today's industry.

Despite the challenges associated with implementing CL, such as student resistance and the increased effort required from instructors, the benefits far outweigh the drawbacks. The research suggests that these challenges can be mitigated with strategic planning, professional development for educators, and structured support for students.

Ultimately, this study provides empirical evidence supporting the integration of CL into engineering curricula, advocating for pedagogical shifts that prioritize active, student-centered learning environments. By doing so, engineering education can better prepare students for their future professions' collaborative and dynamic nature, ensuring they are well-equipped to succeed in an increasingly interconnected and technology-driven world.

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