

# Collaborative Learning in Engineering Education: A Survey of Literature and Studies Toward a More Reflective and Responsive Research and Pedagogy

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The contemporary pedagogical community considers collaborative learning as one of the key elements in the process of successful acquisition and learning of knowledge and practical experiences. It emerged as an alternative to the traditional teacher-centered or lecture-centered educational system. Collaborative learning refers to students' mutual learning, which encourages them to work collectively in developing novel scholastic attainments rather than merely absorbing the information given by tutors. This paper aims to present a survey of literature and studies on collaborative learning and engineering education. Specifically, it surveys studies on engineering students' perspectives, challenges, and resistance to implementing collaborative learning. It also presents studies on the interaction of students' demographic with their perspectives on collaborative learning. The article ends with a synthesis of the surveyed studies that served as a basis in the proposed research agenda, specifically in the New Zealand context, for effective and efficient strategy implementation backed-up by sound educational philosophies and empirical data.

*Keywords:* collaborative learning, engineering education, perspectives, challenges, resistance

## Collaborative Learning and Engineering Education

The present educational system claims to be learner-focused, where collaborative learning is given emphasis to strengthen learners' autonomy (Robles & Torres, 2020). Collaborative learning refers to students' mutual learning, which encourages them to work together in developing cutting-edge academic achievements than absorbing the information presented by their tutors. Collaborative learning is considered as a core element in the

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acquisition of successful knowledge and practical experience. It originated as an alternate form to the customary teacher-centered or lecture-centered educational system. This educational practice puts together three main ideas in a unified process of learning in teams, peer assessment and working in small groups (Sumtsova, Aikina, & Bolsunovskaya, 2018). The fundamentals of collaborative learning started from the principles forwarded by von Glasersfeld (Slavin, 1990) and Vygotsky (Glaserfeld, 1989 in D'Souza & Wood, 2003). It is anchored on the constructivist theory of learning, which emphasizes that people create their own notions and knowledge of the world through experiencing things and reflecting on those experiences, and Bandura's (1977) observational learning theory states that knowledge is gained by imitating and modelling other individuals.

Constructivism advocates for social and communication skills by creating a classroom environment that highlights collaboration and exchanging ideas. In constructivism, students must learn how to clearly articulate their ideas and effectively and efficiently collaborate on tasks by sharing in group projects. Hence, students must exchange ideas, learn to negotiate with others, and assess their contributions in a socially acceptable manner. This is necessary in the actual world since students will always be exposed to an array of experiences in which they will have to collaborate, cooperate, and navigate among the ideas of others (D'Souza & Wood, 2003). In the same vein, collaborative learning is an educational process in which speaking, listening, and reflections, as crucial tools for active learning and enhanced by students using their social skills and mental abilities to: interact and collaborate with peers; develop their cognitive and affective learning outcomes; and make critical decisions concerning themselves (Acikgoz, 1992; Kagan, 1990). The rationale behind this educational practice is that human communities generate knowledge and that learning happens in a dialogical process. Students process the obtained information into knowledge by exchanging ideas, thoughts, and feelings. This will result in their realizations of what is acceptable and relevant to the other members of the academic community. As such, it is surmised that if a student learns to listen to and hear his/her peers, he/she will learn to generate his/her own knowledge (Sumtsova et al., 2018).

In collaborative learning, students acquire more experience, develop better attitudes toward the course, develop their social skills, and learn to acknowledge different perspectives (Kose, Abdurrahman, Aysegul, & Kutret, 2010). They also take some ownership of their learning through reflections. At the same time, tutors are redefined as coaches assisting students' in working toward a set of possible open-ended solutions, and students take some ownership of their own learning through reflection (Sumtsova et al., 2018). This is similar to what Flannery (1994 in Kuwabara, Einbinder, Sun, & Azizi, 2020) mentioned that implementing collaborative learning in the classroom places a tutor in a position of a facilitator and a guide of learning rather than a deliverer of knowledge, and it places students responsible of their learning. Likewise, it supports the observation of Appavoo, Sukon, Gokhool, and Gooria, (2019) that though the concept of collaborative learning has to do with learners learning by themselves, tutors have several roles to play while it takes place. For Laal and Laal (2012), a tutor can facilitate students' learning process and enable them to raise their concerns by constantly asking them questions. While some learners can work on their own while on collaborative works, others rely on a tutor to conduct their group sessions for such tasks as planning and preparing the group sessions, listening to the discussions being held and providing feedback and encouragement. Further, the tutor is also present to deal with any divergence taking place and to monitor the discussion. As Katz and O'Donnell (1999) underscored, tutors in collaborative learning intervene during negative situations and correct the problems that might arise. Finally, for Lentell (2003), tutors in collaborative learning guide learners so that they can understand the subject they are studying and gain more knowledge through collaborative learning.

Engestrom (1992 in Alford, Fowler, & Sheffield, 2014) enumerated three characteristics of collaborative learning. For him, learning is collaborative if the following conditions are met: students work towards a shared problem definition; students cooperate to solve the problem; and students engage in reflective communication, reconceptualizing the process. For Kuwabara et al. (2020), tutors engage three of Chickering and Gamson's (1987) seven principles for good education practices, such as encouraging student-faculty interaction, facilitating cooperation and learning among students, and active learning when collaborative learning is implemented.

Gol and Nafalski (2007) surmised that the notion of collaborative work is inextricably anchored in engineering practice. Hence, collaborative learning is most appropriate and innate in preparing engineering students for the challenges that lie ahead. In engineering pedagogy, the integration of collaborative learning has been recommended as a means of preparation for future professional undertakings. Seidel and Godfrey (2005 in Alford et al., 2014) mentioned that collaborative learning allows tutors to more easily encourage engineering students on the significance of the theoretical knowledge they are learning. It also convinces students to transfer knowledge across contexts and leads to the development of cooperative skills, which are needed by the profession. Likewise, Antov, Pancheva, and Santas (2017) concluded that the approach is intrinsically linked to all aspects of contemporary engineering education.

In engineering classrooms, collaborative learning can be implemented in a number of ways, and each way has a place in providing chances for students to be intellectually active and personally interactive both in and outside the classroom. The most common are informal collaborative learning groups, formal collaborative learning groups, and collaborative base groups. Informal collaborative learning groups are temporary, ad hoc groups that last from a few minutes to one class period. They are mostly used in lecture-dominated classes and are used to focus students' attention on the material to be learned, set a mood conducive to learning, help organize the material to be covered in a class session in advance, ensure that students cognitively process the material being taught, and provide closure to a class session. Meanwhile, formal collaborative learning groups are more structured than informal ones in which students are given more complex tasks. Formal collaborative learning groups typically work in groups longer than informal collaborative learning groups. Finally, collaborative base groups are long-term, heterogeneous collaborative learning groups with stable membership whose primary responsibility is to give each student the support, motivation, and assistance he or she needs to make academic progress. Base groups personalize the work required and the course learning experiences. These base groups remain the same during the entire course and longer if possible (Treisman, 1992).

### **Purpose and Organization of the Paper**

The current integrative review aims to survey literature and studies on engineering students' perspectives, challenges, and resistance to the use of collaborative learning. Studies on the interaction between learners' demographics and perspectives on collaborative learning will also be presented. The latter section will provide a synthesis of the surveyed studies that will be the basis for the conclusion that will set the direction for future research undertakings.

### **Students' Perspectives on Collaborative Learning**

A number of studies have revealed that engineering students have accepted the concept of collaborative teaching and learning. The early study of Koehn (1995) and the more recent study of Lin (2015) have revealed that undergraduate engineering students perceive that working in groups is an excellent experience for it helps

them develop their cognition and communication skills which will be beneficial in their future undertakings. The foregoing findings were disputed by Pearsons (2010), who enumerated students' communication with classmates, time in performing the tasks as a group and in reaching out to other group members, and distribution of task as some of the pressing concerns in collaborative learning.

Dass et al. (2021) cited researchers (i.e., Yee & Yoo, 2018; Seemiller & Grace, 2017) who emphasized students' satisfactory acceptance of collaborative learning approaches. They underscored that though students want independent learning, they prefer group work as well. This was corroborated by earlier findings (i.e., Thacker, 2016; Desai & Lele, 2017) that the present generation of students prefers collaboration and interaction.

Alford et al. (2014) did an exploratory investigation on the perspectives of freshmen engineering students taking an Introductory Engineering Course toward collaborative learning. Students' perspectives were obtained at three-time points during a first-year project-based, team-based design course: before students started working in teams, after they have completed an initial small-scale design project in a four- or five-person team, and after they have completed a larger-scale design project with a different, similarly-sized team. Qualitative data reveal that prior to students' collaborative learning experience, many students hope rather than believe that they will have better team experiences in college than in high school. Meanwhile, the quantitative analysis shows a fairly wide spread of ratings on perceived fun, frustration, and learning with teamwork. Quantitative results further revealed that midway through the class, after the first project, perceived fun and learning decreased from pre-collaborative learning expectations, while qualitative analysis shows that the perceived frustration dropped. Finally, in the last survey, after the completion of the second project, quantitative results show somewhat of an improvement in perceived fun and learning, and frustration remains more or less the same from the midterm point. Qualitative data show positive comments on the opportunities to learn from difficult situations and negative comments on students' own procrastination.

### **Students' Challenges and Resistance to Collaborative Learning**

Scholars (e.g., Seidel & Godfrey, 2005 in Alford et al., 2014) pointed out that the increased use of collaborative learning in undergraduate engineering programs has downsides that engineering educators have to prepare for. For them, the lack of planning and monitoring on it can allow students to freeload and receive credit for a group accomplishment without contributing substantially to it.

Gol and Nafalski (2007) mentioned the need for engineering educators to recognize that students enrolling on engineering degrees are from vastly different educational, cultural, and personal backgrounds. For instance, students will have their preferred learning styles and will process the information they receive in a number of ways. As such, students may find in collaborative work the opportunity to choose a particular task and avoid others. Likewise, Atman et al. (2010) found out that collaborative learning may be advantageous to some students and disadvantageous to others. In engineering courses, women and minorities are the ones who are more likely to express dissatisfaction with collaborative learning, underscoring the fact that they are unheard of and marginalized. In terms of task distribution, the same authors found that female engineering students are more likely assigned to complete project planning and communication work, while male students are assigned to technical planning and hands-on building. Nonetheless, the previous authors did not specify in their study if students preferred to assume on gender-specific tasks or were pushed by their groupmates into those responsibilities.

The study of D'Souza and Wood (2003) among freshmen engineering students in Australia pointed out that resistance from lecturers and students, difficulties with modes of operation, group dynamics, and organization issues are some of the difficulties faced in the implementation of collaborative learning methods. An earlier study of Springer et al. (1999) found out that students with better scholastic and intellectual attitudes may feel that their progress is retarded due to lack of worthwhile contributions from the weaker team members. This was confirmed by Taylor's (2011) findings that students may devalue the knowledge of their peers and feel that peer-to-peer interactions lessen the time they would have listened to the tutors' discussion. Similarly, Gokhale (1995) noted that some negative experiences in collaborative learning come from personality clashes and irresponsibility within groups. This was supported by the recent findings of Virga et al. (2014) that personality issues and conflicts may arise while working in a group that causes students to complain about disliking other members. For example, students with strong personality traits can dominate group-decision making, which contradicts one of the basic premises of collaborative learning that every student must be given a chance to contribute to the team's learning outcomes.

In 2018, Stover and Holand reviewed the works of Howard (2015), Taylor (2011), Beebe and Masterson (2003), Karau and Williams (1993), and Allan (2016) on students' challenges that resulted in the latter's resistance to collaborative learning. For Howard (2015), students may feel angry when collaborative learning is employed since they feel the tutor has changed the rules of an acceptable learning environment, while Taylor (2011) reported that students often dislike collaborative learning due to the group's dynamics and accountability and its nature in which students are required to collaborate, communicate, delegate, and rely on each other. Beebe and Materson (2003) mentioned that group dynamics in collaborative learning may exert pressure on the group to reach a majority opinion that may cause individual group members to conform to decisions they do not support entirely for them to avoid conflict. For Karau and Williams (1993), collaborative learning often leads in uneven participation due to social loafing, which is the "tendency of individuals to expend less effort when working individually" (p. 681). Finally, Allan (2016) found that students resisted collaborative learning as they resent all group members receiving the same mark though a few members of the group have not exerted the same effort with that as the other members.

### **Influence of Students' Demographics on Their Perspectives Toward Collaborative Learning**

Burke (2011) mentioned that while many research studies have found benefits of incorporating collaborative learning, it is inevitable for instructors to experience student resistance. For Tolman and Kremling (2017, p. 3), student resistance is an "outcome, a motivation state in which students reject learning opportunities due to systemic factors". The same authors opined that student resistance is not a trait that is part of a student's personality enduring over time but is a fluid motivation state that can be influenced. They also mentioned that environmental forces (i.e., family background, social status, and cultural identity) and students' previous negative experiences with collaborative learning in the classroom are external factors that have an impact on student resistance. Meanwhile, internal forces that impact student resistance are cognitive development and metacognition. In line with this, Appavoo et al. (2019) performed an analysis to investigate any interaction between learners' demographics (e.g., gender, age group, and marital status) and perspectives on collaborative learning. Results of the analysis revealed that no significant differences in students' perspectives on collaborative learning had been established when they were grouped based on their demographics.

### **Toward a More Reflective and Responsive Use and Research on Collaborative Learning**

Results of the integrative review of literature and studies underscore that collaboration is an important aspect of engineering education since professional engineers themselves work with one another and with professionals in various domains. As Gol and Nafalski (2007) surmised, collaborative learning is intrinsically associated with a number of today's highly held paradigms (e.g., active learning, student-centered learning, problem-based learning, project-based learning) that are considered as the world's best practice. Though early implementation of collaborative learning encountered resistance from both educators and students as it precisely opposes the traditional teacher-centred learning experiences and its efficacy was doubted (e.g., Atman et al., 2010; Beebe & Materson, 2003; D'Souza & Wood, 2003; Godfrey, 2005; Gokhale, 1995; Howard, 2015; Karau & Williams, 1993; Pearsons, 2010; Seidel & Allan, 2016; Springer et al., 1999; Taylor, 2011; Virga et al., 2014), its efficiency and effectiveness in students' academic performance, relationship with peers and faculty, and attitude toward tertiary learning experience have been validated in over 20 years of empirical data (e.g., Alford et al., 2014; Dass et al., 2021; Desai & Lele, 2017; Koehn, 1995; Lin, 2015; Seemiller & Grace, 2017; Thacker, 2016; Yee & Yoo, 2018). Upon closer review and analysis of the surveyed literature, it can be said that collaborative learning is the obvious natural choice for engineering education since engineers have to learn to deal with others, evaluate the outputs of their peers, and be open to criticisms and various perspectives. For nearly four decades, engineering education reformers have advocated for increased collaboration in students' engagements in preparation for the professional reality.

Indeed, implementing collaborative learning without considering the scholarly empirical-based approach can be costly as well as disruptive and detrimental to students learning. Engineering educators need to be cautious in implementing collaborative learning, for it will bring positive and negative impacts on students. What is needed is the use of the strategy as backed up by sound and deeply-rooted educational principles and empirical data from further studies. Engaging in collaborative learning research can lead to further improvements in implementation, which in turn can result in a virtuous research cycle. In the New Zealand context alone, this topic has not yet been fully explored. Many of the studies surveyed were done in the American, European, Indian, and Arab settings. It is of significant interest to explore how engineering students in New Zealand educational institutions perceive collaborative learning in their classes. This is in relation to what Torres and Santos (2021) mentioned, that New Zealand has a diverse society in a globalized milieu, and many people from the Pacific and Asia have decided to pursue education in the country. Future studies may also endeavor to identify classroom practices that may address both the tutors' and students' challenges with collaborative learning so resistance from both of them will be lessened and will just become a thing of the past soon.

For educational institutions to stay competitive, there is a need to explore and adapt new teaching and learning strategies through rigorous research and innovation in engineering education. Such initiatives, as Mohd-Yusof et al. (2015) mentioned, will prepare engineering students to come up with forward-looking and cutting-edge initiatives, develop new designs, products, and services, and deliver to serve the communities, and innovate continually to support the industries. Professional development in the forms of training, seminars, mentoring, and establishing networks can be effective in instructing and inspiring and encouraging tutors to use modern and multifaceted practices, particularly student-oriented practices and enhanced activities. As the Organization for Economic and Co-operation Development (2009 in Robles & Torres, 2020) underscored, tutors who report using

student-oriented practices and enhanced activities relatively often are generally more motivated to learn and apply innovative teaching strategies and thus endeavor to more professional development. Likewise, as Stover and Holland (2018) put it, today's complex workforce requires workers to have a strong level of communication and collaboration to solve the complex issues facing our society. In closing, it is noteworthy to mention that the key success factors in using collaborative learning require tutors and students to grasp and engage in engineering education-related concerns, be committed, work in teams and embrace and address all the challenges ahead.

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