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Teamwork Assessment in Engineering Education
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Teamwork is an essential competency for engineering graduates. Companies use high performing teams to efficiently adapt and meet complex societal demands. In several engineering programs students are expected to work in teams; however, teamwork is seen by most students as a course requirement to get a grade, rather than as a skill they need to master to become effective engineers. The purpose of this study is to understand the experiences of students and measure the effectiveness of a teamwork training model used to manage large teams and promote teamwork competencies in engineering students when working on a real senior capstone design project. We used a mixed methods approach. For quantitative data, descriptive and inferential statistics are reported to understand how the students' perceptions about different teamwork constructs changed after the semester concluded. In addition, qualitative data were collected by semi-structured interviews. Results suggest that the teamwork model used to train the students was effective in helping them achieve their desired teamwork competencies and overcome the challenges of working in large teams. Students reported that they felt more ready to face the professional engineering working environment as they now recognize teamwork is a key required competency.

Keywords: teamwork; large teams; problem-based learning; design; mixed methods

This study has investigated the natures of collaboration, group-based strategy use, and perception of assessment, as well as interactions among these aspects, by examining group performance in engineering students' first experiences of a problem and project-based learning (PBL) method. Empirical evidence was gathered from focus groups and observations of 91 engineering students in Qatar who worked in 17 project teams. Qualitative analysis results identified three patterns of conceptions of collaboration and five categories of group-based strategies in a hierarchical order. Findings of the study extended the current understanding of self-regulated learning by providing evidence from a group form in a collaborative learning setting. Characteristics of Middle Eastern students are highlighted regarding their favoring division of tasks and relying on seniors as major sources of knowledge authority. Quantitative analysis identified a significant relation among conceptions of collaboration, group-based strategy use, and team performance. Students' perceptions of assessment remain diverse, suggesting it may take longer than expected for students to gain a deep understanding of constructively aligned alternative assessment in PBL. The results provide a few implications for instructional design in general and PBL implementation in particular.

Keywords: conceptions of collaboration; group-based strategy use; perception of assessment; PBL; Qatar

Software work is normally developed in groups. As a result, there is a need to develop teamwork competence in related activities such as, software engineering education. In higher education educational settings, courses often propose several tools for student groups to either guide or support their work. In this paper, authors present main results and lessons learned from courses on software engineering. Specifically, the aim of this paper is the study of the selection and the adoption of software engineering tools by students working in teams, in the context of a software engineering course. The purpose of the study is analysing the students' decision making process and reasoning strategies to such selection. In this scenario, driven by a project based learning approach, a qualitative study on the use of specific tools to support group work was conducted. Results reveal that students demonstrate a rational decision making process based on logical efficient reasoning. As consequence six lessons have been learned: *everything in one place; the new over the known; freedom over imposition; performance and freedom; social influence and secondary role of project management*. In addition, these six lessons have been compared with previous literature in the topic and backing them up with main theories in the field. Finally, authors reflect on the implications of such lessons learned analyzing deeply aspects like freedom of choice, performance, tools features, imposition and social influence, to bring a set of grounded argumentations to the reader.

Keywords: software engineering education; teamwork; software engineering tools; decision-making; qualitative study, freedom of choice

Engineers and technologists play an integral role in the global economy by responding to complex problems with innovative solutions. These roles are not acted on in isolation thus making teamwork an important competency. While the importance of mastering the competency concepts is known, assessing teamwork is not so straightforward. The purpose of this study was to gain a clearer understanding of student perceptions on teamwork. Researchers distributed, collected, and analyzed qualitative data from three different courses at a Midwestern University. Participants were enrolled in three different levels (engineering design –

freshman (n = 26), Construction Management Technology – sophomores (n = 42), and Aviation and Transportation Technology – juniors (n = 30)). Specifically, researchers utilized the Comprehensive Assessment of Team Member Effectiveness (CATME) system and reflection prompts. A total of (n = 98) reflections were collected. After a thematic analysis using NVivo, results indicated students reflected differently upon teamwork depending on the project type, context, educational background, experience, and maturity of the team. The analysis yielded evidence towards the need to not only increase the opportunities for teamwork but to intentionally incorporate peer – and self-assessments. These assessments may be completed through evaluation and reflection.

Keywords: self-regulated learning; competency; proficiency CATME; reflection; active learning

In Building and Construction Engineering field, one of the most needed and valued skills by the professional sector is the teamwork ability. The affirmation is based on previous researches that have demonstrated how such competence is not only required in this sector, and identified as key by the professional world, but also necessary in academic processes. Based on this premise, the present work focuses its research on the design, implementation and assessment of a methodological change applied in the Final Degree Project (FDP) of Building and Construction Engineering degree, going from being an individual work to a teamwork. It has been demonstrated, how main specific competences required by professional sector are properly worked and validated in the design of the current curricula and in the FDP development. However, the same researches have allowed us to identify transversal or generic competence as teamwork that should be improved. Starting from current FDP development, traditionally based on the PBL (Project Based Learning) method, this work is focused on evolving FDP towards a CBLI approach (Challenge Based Learning Initiatives), through a collaborative work between student's teams, assessing what happens during the different stages of the learning activity and what each team member has done. For the proposal assessment, we focused on a mixed study (quantitative and qualitative), which will allow us to analyze in a specific way the relationship between the research variables such as motivation, competency requirements and academic results. This approach bases its effectiveness on previous researches that demonstrate its usefulness when study sample is reduced, as the case in question.

Keywords: teamwork; generic competences; mixed assessment; building and construction learning

Obtaining evidence on the acquisition of the teamwork competence, from students throughout their training, is demanded by both accrediting agencies of High Education degrees and future employers. This competence has been, and still is, of great importance in general and in degrees in engineering in particular. Based on previous research studies, evidence to evaluate teamwork competence acquisition is classified in three dimensions: (i) the individual dimension, acquired by each team member; (ii) the group dimension, composed of results from each teamwork; and (iii) the result dimension, which consists of deliverable products throughout the teamwork process. One of the methods which takes the three dimensions into account, the one that helps train and evaluate the teamwork competence, is the "Comprehensive Training Model of the Teamwork Competence" method. In this paper, we will show that through this method, more than 50 teams have generated evidence which can be used as learning resources. All this evidence has been stored and organized (through an ontology) in a semantic repository. The generated evidence is retrieved by using an inference engine through the metadata of ontology. This study, which has validated the resources obtained from the repository, was relevant for a specific information demand. To this end, results automatically obtained by the search engine were compared with those manually found by teachers who are experienced in the teamwork competence.

Keywords: teamwork; active methodologies; repository; ontological search; WordPress plugin

Project Based Learning (PBL) is a methodology that requires students working in teams. Based on the Agile philosophy, this article presents a procedure (and its tools) to assess individuals in a team based on, not only the final project, but on the process, where each contribution to joint work is better seen. Students are asked to fix SMART objectives, tasks, dates and people in charge for each one and include it in the project status table. Students make weekly follow up meetings (with or without the teacher) to share and review information, results and project process. Portfolio including the meetings minutes, peer and self-assessment of teamwork and project status table provides teachers a rich information to evaluate students and give them feedback. This iterative process of continuous review and short-design time frames helps the team to quickly adapt the projects and the teachers to detect team problems. We propose two rubrics: one to assess individually teamwork using a peer and self-assessment; another to evaluate learning outcomes in each the delivery, both individually and within the team. Teachers' and students' perceptions while using this Agile methodology have been collected from a qualitative approach. Proposed rubrics along the whole process give the required feedback to teachers and students making a 360^{o} assessment and introduces individual assessment of learning outcomes. Overall, the results obtained are quite positive in terms of working atmosphere, quality of the work, learning outcomes achieved and assessment. However, a careful planning and assessment is needed.

Keywords: project-based learning; teamwork; agile methodologies; scrum methodology; assessment; rubrics

Teamwork is increasingly being acknowledged as a necessary part of the engineering workplace, therefore engineering educators may feel a responsibility for teaching teamwork skills to students. Engineering educators cannot improve their students' teamwork skills without first being able to practically diagnose the students' strengths and weaknesses. The present paper focuses on translating team science to a useful checklist for engineering educators to monitor their students' teamwork skills. A qualitative data-sorting analysis of 286 behaviors from 88 interviews resulted in the present checklist, which is broken into six components of teamwork processes and emergent states. The checklist details effective and ineffective team-wide or team member behaviors in such teamwork categories as communication, cognition, coordination, coaching, cooperation, and conflict. While not formally validated, the checklist is empirically derived and in-line with the literature on team performance. This tool will allow educators to uncover what teamwork components require further skill development in their students' project-based learning courses.

Keywords: teamwork skills; checklist; PBL

Given the increasing emphasis on teamwork in engineering education, our interdisciplinary research team has combined expertise in the science of teamwork and best practices in engineering education, spending three years investigating the functioning of engineering design teams at our university. This effort has culminated in a number of research efforts incorporating both qualitative and quantitative techniques as well as cutting-edge analytical methods. This paper seeks to summarize our findings, highlighting strengths and drawbacks of these methods and providing ten student engineering team findings that have emerged from our research in order. Our findings thus far, centered on topics such as team leadership, diversity, psychological safety, and

performance, have provided novel insights within our institution, but also advance the science of teamwork and engineering education. Accordingly, we shed light not only on the implications of our findings for engineering education, but also on the types of findings that might be elicited through various approaches to teamwork assessment in engineering education.

Keywords: teamwork; teamwork assessment; methodological approaches

In work environments, it is essential for engineers to have a high level of teamwork competence. Therefore, engineering education programs aim to provide an environment where students can experience working in teams. In this study, perceptions and co-regulation of computer engineering students regarding teamwork were examined in a hardware course. A teamwork oriented approach based on individual and group reflections of students was designed and applied during an 8 week project study with the participation of 56 sophomore students of a public university in Turkey. In order to analyze different aspects of the teamwork acquisition process, convergent parallel mixed-methods design was utilized by using both quantitative and qualitative data. Quantitative data were collected by co-regulated learning questionnaire which was applied as pretest and posttest, and teamwork evaluation form that was used for self and peer assessment. Qualitative data were gathered by reflections and focus group interviews. The findings indicated that teamwork oriented approach had significantly increased co-regulation skills of students and they gained positive perceptions towards teamwork. Since most of the teamwork studies in computer engineering programs have been conducted in software engineering courses, applying a teamwork oriented approach in a hardware course provides a valuable contribution to the literature.

Keywords: teamwork assessment; co-regulation; students' perceptions; reflection; self and peer assessment; computer engineering education

Engineering Design practice is increasingly becoming a global activity where individuals, who are geographically distributed, work together as a team. Although the mainstream core of engineering design trains students to face teamwork from a co-located standpoint, existing studies point out the benefits and tradeoffs of distributed team training. This article explores the complexities of working in distributed teams by assessing distributed team experiences on three different continents. To achieve this goal, the study was organized in two stages. In the first stage, a framework was developed based on a yearlong mixed-methods study where four engineering teams from two prestigious universities in Chile and the U.S. worked together on open-ended problem-based challenges. Subsequently, the data from other 11 teams including distributed work among students in Chile, the U.S., and Finland, in the period spanning from 2016 to 2017, was collected and analyzed. A time tracking research instrument was created assessing how teams allocate their efforts within the design process and how this allocation varies across co-located and distributed teams. In addition, 10 semi-structured interviews were conducted with students from the first stage in order to triangulate the information. Findings show that distributed and co-located teams spend similar amount of time in convergent and divergent design activities. Moreover, evaluators identified improvements in the end solutions designed by students since there seems to be a cultural and academic complementation in the solutions proposed by distributed teams. All teams tend to use more time on convergent activities rather than divergent ones, especially when preparing presentations for a larger class group. Special attention should be paid on the convergent stages of teams' design processes in order to provide the right educational scaffolding to facilitate learning. This study sought to shed a light on the possibilities of working with geographically distributed teams, and we found that, overall, the trade-offs are not significant.

Keywords: engineering design; teams; distributed teams; time allocation; time assessment; teamwork

The development of adequate work group activities in engineering is a tough task, and their efficiency can be highly influenced by students' attitude. In this article, an evaluation of teamwork (chemical and computers laboratories) related to Chemical Engineering subjects is presented, as well as the conditions for an effectual development of work groups and students' attitude for guaranteeing an efficient learning. By using adaptive tests, the most effective self-regulated learning strategies and their relationship with work groups is defined. By doing so, it is demonstrated that teamwork can be helpful for students, but it is not risk free if students do not focus on the tasks. In this sense, results show that students with a passive attitude in the group reach minimal scores, i.e., do not learn concepts or, even do not pass the final examinations.

Keywords: adaptive tests; chemical engineering experimental activities; teamwork

The University of Ottawa's Faculty of Engineering is home to multiple rapid prototyping facilities and entrepreneurship spaces. These include a makerspace, a machine shop and a design space for any student to use free of charge. In the Makerlab, students take courses that introduce them to collaborative project-based learning, engineering problem-solving and prototyping. The goal of the first- and second-year engineering design courses is to introduce engineering design processes, time and project management, and analysis, prototyping and testing. In each course, students work in groups on a semester-long project to meet the needs of a real client whom they meet with three times over the course of the project. The objective of this paper is to understand the impact of each team member's personality, more specifically the Big Five personality traits (openness, conscientiousness, extraversion, agreeableness and neuroticism), on team dynamics and team performance with regards to their project throughout the semester in a project-based learning environment. Factors considered are gender, GPA, the Big Five personality scores, final peer evaluations and team dynamics, project manager evaluations and project grades. Multiple regression analysis is conducted to determine if any of the factors listed influence team performance and dynamics as well as individual project grades.

Keywords: engineering design; personality; team dynamics; project-based learning

In their final year, engineering students in Canada work in teams on a design project. These projects require significant collaboration and, as such, the project's success is largely dependent on the students' teamwork. This work presents an exploratory study of capstone design teams in a large engineering school in Canada. The goal of the study was to draw valuable insights about the teamwork experiences, skills and gaps of students in capstone design teams. These insights will support evidence-based development and improvement of teamwork training for engineering students. The study was conducted in two phases. First, semi-structured interviews with 12 instructors of capstone design courses solicited their perspectives on students' capstone design teams. Findings from the instructor interviews and related literature were used to design a student survey. The survey was administered to more than six hundred fourth-year engineering students to further explore capstone design teams' dynamics. We collected information on students' team formation, distribution of tasks and roles in teams, project management methods used, and the different types of conflicts experienced. In addition, we investigated the potential links between those variables and team effectiveness and enjoyment. In general, our results provide strong evidence that having clear roles, a high degree of a match between students' interests and skills with their assigned tasks, similar expectations about the outcomes, a clear project

management plan, and lower levels of conflicts in student teams are significantly correlated with perceived team effectiveness and enjoyment. We discuss the implications of our findings for targeted instructional interventions on required teamwork skills for students.

Keywords: team process; team effectiveness; project management; capstone design

This study is the result of a research developed in the course of an intervention in a Brazilian Worker Recovered Factory (WRF) in Brazil performed by a team of fifteen engineers from different areas and levels of training. According to the principles of the Ergonomics of Activity, the intervention sought to analyse and propose solutions to company problems from a participatory process, which also includes workers at all stages of their development. We were able to analyse the intervention through direct participation in the project as a member of the team of engineers (participant research), seeking to draw contributions on engineering training from practice in real situations (action research). The intervention showed the possibility of obtaining a supervised apprenticeship process, reducing complexity without losing touch with reality, creating conditions for students to learn by practice, and making mistakes without causing damage to the host company. This process showed that is possible to overcome the purely theoretical formation of the engineer, allowing developing teamwork skills and the collective construction of emerging and socio-technically responsible solutions.

Keywords: teamwork; participation; industrial assessoring; socio-technical education

Peer assessments can be used in team project based design courses to identify problematic individuals and team dynamic issues early on so that they can be addressed and hopefully resolved before it is too late, as well as provide a basis for calculating individual grades for team project work. Although peer assessments can take on many forms, their goal is to measure individual performance within a team as rated by their peers. In this study, ITP Metrics is used to provide individual scores based on five team performance dimensions. Two different courses using different peer assessment modalities are considered. In the first case, peer assessments are conducted at the mid-point and end of the course, whereas in the second case, peer assessments are conducted after each deliverable. Results show that two peer assessments over the term are not enough to provide sufficient scaffolding to problematic individuals or teams. However, peer assessments conducted in Tuckman's forming or norming stages provide very little additional information. Multiple peer assessments conducted during the storming stage before the mid-point of the term, along with appropriate scaffolding, is shown to be most efficient in improving individual and team performance. In fact, teams that do not receive additional scaffolding are found to have deteriorating team dynamics overall as the term progresses through the second half of the term. Special cases are also considered. Moreover, the correlation between peer assessment results and team grades is shown to increase over the term, demonstrating the importance of understanding peer assessment results throughout the term. Future considerations are required to ensure peer evaluations are best used in modifying individual grades.

Keywords: peer assessment; project based learning; team based projects; engineering design

Teamwork is one of the key issues in engineering projects success. Unfortunately, due to the high number of interactions, the assessment of collaborative tasks remains a challenge. Wikis are web-based systems that support collaborative work in enterprise engineering project documentation providing quantitative data from the members' contributions and interactions. While this objective data is interesting for the teamwork assessment, a qualitative assessment process can provide a complementary approach. We propose an architecture that combines information from both sources to conduct a scalable assessment of the teamwork in a wiki. It was implemented in a course of the degree on Computer Engineering using specific developed software tools and Process Mining techniques. Process Mining tools automatically apply artificial intelligence algorithms to extract knowledge from real processes and discover models. These models provided evidence of conducted behaviour. The actual dynamics of the teams in the wiki were automatically detected and could be analysed for assessment purposes. Finally, the followed mixed approach allowed a detailed and scalable teamwork skills assessment process.

Keywords: teamwork assessment; quantitative assessment; qualitative assessment; wikis; collaborative learning; process mining

Engineers have to work with many people, each with various level of knowledge, as a team because most work in the engineering field involves complex projects. To teach teamwork skills properly in engineering schools, the teamwork skill levels of students should be assessed. Many professors have measured teamwork skills in their classes, yet they still have questions as to how they can teach and measure teamwork skills.

This study aims to identify teamwork skills and their subordinate areas necessary for engineering students as well as to develop the appropriate scales to measure such skills.

To achieve such goals, a literature review and survey were conducted. Teamwork skills and their subordinate areas were reviewed. A survey was administered to 343 students of three engineering schools in the Republic of Korea and a factor analysis was conducted.

The scale was completed with five factors, each of the common and individual skills. Reliability, cooperation, a sense of responsibility, listening courteously, and adaptability were selected as the common skills; and for the individual skills, the roles of leader, innovative executor, mediator, terminator, and judge were suggested. The abilities needed for each role were defined as leadership, problem-solving ability, interpersonal relationship ability, communication ability, and decision-making ability.

The components of the teamwork skills that were developed in this study can be used to measure teamwork skills and as preliminary data for the development of education programs needed to concretely improve the teamwork skills of students.

Keywords: teamwork skills; teamwork skills scale; common skills; individual skills; engineering education

This study focuses on the impact of team formation approach on teamwork effectiveness and performance spanning three years of instruction of the chemical engineering unit operations laboratory, which is an upper-level undergraduate laboratory course. Team formation approaches changed each year, and assessment tools, including peer-assessment, academic performance, and course evaluations, were employed to evaluate team performance. Approaches included three cases: instructor-selected teams based on GPA with the objective of a similar cumulative average GPA for each team, student self-selected teams, and a combination of self-selected teams with instructor-selected teams for a final experiment. For the third case, new teams were assigned based on a common interest to learn about a specific final laboratory experiment or research topic, and the instructor identification of both low- and high-performing students in the prior teams. Team effectiveness and performance were assessed using CATME, a teamwork VALUE rubric developed by the Association of American Colleges and Universities (AAC&U), and numerical peer-contribution forms. In addition, assigned team leaders for each experiment provided feedback regarding individual team member