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Collaborative Project: Exploring the Experiences of Engineering Students' Engagement in Face-to-face and Virtual Peer Learning

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Abstract: In this study, we investigated students' perception and learning outcomes related to the emerging trends in virtual and face-to-face collaborative learning environments. We used the constructivist model as a frame to explore students' perceive benefits of virtual and face-to-face environment to facilitate collaborative projects before they were able to maximize the quality of their learning outcomes. The findings from the analysis of two student feedback surveys indicated that students enjoyed being able to interact and create 3D objects in a virtual environment. However, they had to devote more time and extra practice to this collaborative approach in order to get the most out of the virtual environment. The findings in virtual and face-to-face approaches also revealed that students from diverse backgrounds, experiences and expectations reported that differences in English language proficiency between local and international students sometimes caused communication difficulties and misunderstandings. Hence, cross-cultural communication skills between team members to provide constructive feedback and more clarity in communication needs to be carefully considered in helping students to support one another and maximize student progress.

Key words: peer and collaborative learning, CAD, CAE, virtual, face-to-face

1. Introduction and Background

Virtual collaboration in teaching and learning for undergraduate degrees, particularly engineering disciplines, has attracted the interest of researchers keen to prepare students to be competitive in the global engineering market. Over the past two decades it has been increasingly apparent that graduates are expected to develop the ability to work in multidisciplinary teams, and work and communicate effectively in global virtual environments (Ríos et al., 2010; Thoben & Schwesig, 2002). Multinational companies in the aerospace, automotive, defence and manufacturing industries are now seeking engineers and graduates who can work in diverse environments to address different stakeholders' needs, minimize overlap design delegation issues and optimize costs. Also, in order to survive in the competitive global market, engineers and designers have to find ways to accelerate the design and manufacturing process by shortening the development cycle to bring new, high performance and reliable products to the market (Liu et al., 2004; Verhagena et al., 2012). The complexity of modern products requires various disciplines to collaborate to solve complex issues. Global collaborative design and virtual design

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platforms are essential to facilitate relations between the many participants in the design process, and allow engineers to perform real-time geometric modifications and concurrent designs to ensure competitiveness in product design and development (Liu et al., 2004; Rahmawati et al., 2014).

The basic design process has not changed, but there have been major advances in the supporting technology, particularly in the Computer-Aided Design (CAD), Computer-Aided Engineering (CAE) and analysis tools that increase the capability to develop engineering products at lower cost and optimal speed. In line with the constantly evolving requirements of industry, 3D virtual environments that support collaboration have been adopted by many higher education institutions (Cruz et al., 2014; Silvia & Beatriz, 2012; Spinks et al., 2006; Ye et al., 2004). A number of studies have evaluated students' learning performance in virtual collaborative learning environments (Goold et al., 2006; Jou & Wang, 2013; Kanematsu et al., 2013; Lee & Kim, 2005; Silvia & Beatriz, 2012; Yeh, 2010) and this research has indicated that the students generally had a positive attitude toward working collaboratively within the virtual environment. However, little work has been performed to determine the virtual environment's role in affecting students' perceptions of the skills and competencies required by today's virtual global environment (Wellington et al., 2002) Further work also needs to be done to see how the virtual environment affects student work in both geographically and culturally diverse settings (Dawes & Senadji, 2010).

The purpose of this study was to evaluate the performance of peer learning and collaboration for first-year undergraduate engineering students, in relation to engaging in face-to-face and a CAE virtual environment. We aimed to determine students' perceptions of their development of knowledge, skills and professional attitudes that highlight emerging pedagogical issues for higher education. Hence, we intended to address the following research questions:

(1) How often do students participate in team discussions and team activities;

(2) Does the use of virtual CAE tools to manage engineering projects have any effect on knowledge, skills and attitude, when compared with students enrolled in traditional engineering courses;

(3) Can collaborative design projects be implemented when the student population is diverse in terms of backgrounds, experience and expectations;

(4) What are the students' perceived benefits of virtual CAE tools relevant to their studies and future?

2. Theoretical/Conceptual Framework for the Study

The conceptual framework for this study was derived from surveying and analyzing the current practice and emerging trends in virtual environments and face-to-face peer learning and collaboration, particularly in engineering design. Initially, it was observed that virtual environments can be described in a number of different ways: "online", "digital", "electronic", "computer-based", "virtual space" and "web-based environments" being some of the commonly used terms (Dillenbourg et al., 2002).

We also found that it was important to consider how we defined "collaboration". The description provided by Patel et al. (2012) that "Collaboration involves two or more people engaged in interaction with each other,… working towards common goals" (p. 1) was the most useful as it represented how engineers collaborate within the industry. Indeed, further research showed that the global design industry has required collaboration to be integrated into virtual environments to facilitate knowledge sharing, decision making and efficient communication (Liu et al., 2004).

Data suggests that this trend will continue, both within industry and in the higher education sector (Poirier and Feldman, 2007). According to Birenbaum (2003): "emerging technologies of computer-supported collaborative learning provide increasing opportunities for fostering learning in such an environment by creating on-line communities of learners. [...] It offers a dynamic collaborative environment in which learners can interact, engage in critical thinking, share ideas, …" (p. 21). Also, Rodriguez-Donaire et al., (2010) suggests that "the existence of digital environments aids university teaching practice. […]. Besides, the use of digital platforms encourages and facilities students', professors' and other user's participation by collaborating and sharing knowledge and information" (p. 114).

Studies in the literature, which compare different type of learning environments and the tools used, show mixed results in students' performances. Some researchers have found that collaborative learning may be very effective in virtual environments (Campbell et al., 2008; Hoag & Thomas, 2000; Tutty & Klein, 2008). Campbell et al. (2008) adopted a quasi-experimental approach to compare the educational attainment of two groups of postgraduate students: students who attend face-to-face discussion seminars; and students who participated in online discussions. They found that the students who participated in online discussions were more actively engaged in online activities and their average assignment mark was 4.7 times higher than students in face-to-face discussion. In contrast, some studies assert a more positive trend in student achievement and performance in face-to-face collaboration settings compared with virtual environment settings (Johnson et al., 2000; Siampou et al., 2014). According to Siampou and colleagues, students who collaborated online had a lower initial performance and their mathematical models were found to be slightly worse than in the face-to-face group.

When comparing the performance of face-to-face and online environments, other researchers did not find any significant differences in learning performance in university students (Dell et al., 2010; Horspool & Yang, 2010; Larson & Sung, 2009). For example, a study by Larson and Sung (2009) that compared the undergraduate students performances, i.e., student satisfaction, learning effectiveness and satisfaction, and final grades, who were taught by the same instructor using face-to-face, blended and online delivery modes. They found no significant differences in student performances in different delivery modes.

These comparisons of virtual and face-to-face learning helped us formulate our research questions and the variables that could potentially be considered in the current study. In particular, we were interested in finding out how the students perceived their own ability to collaborate in a virtual environment, compared to a face-to-face environment. This takes a constructivist approach: the students need to perceive that their environment facilitates collaboration before they will be able to maximise the quality of their learning outcomes.

For the questionnaire used in the study, the framework proposed by Platt et al. (2014) was applied. According to Platt et al. the systematic study of student perceptions, in terms of flexibility in learning process, level of interaction and knowledge gained in learning environments (online or face-to-face), is important so that administrators and educators can make more informed decisions on pedagogy, course design and educational offerings.

3. Study Populations and Methodology

3.1 Sample

The study was performed on first-year engineering students enrolled in large classes in the School of Aerospace, Mechanical and Manufacturing Engineering at RMIT University, Melbourne, Australia. The same cohort was enrolled in three different engineering courses: (1) a face-to-face peer learning and collaboration in a design and build project (a spaghetti bridge); (2) face-to-face peer learning and collaboration within the Engineers Without Borders (EWB) project; and (3) an engineering design course that used a virtual CAE platform to facilitate peer learning and collaboration. A brief description of the courses, teaching activities and assessment tasks is shown in Table 1.

Table 1 Overview of Engineering Courses Surveyed

Course	Course Brief Description	Teaching Activities	Assessment Tasks
1	An introduction to structures and solid mechanics	Lectures, quizzes, laboratories, assignments, tutorials and a final exam	Online quizzes and class tests (25%) Spaghetti Bridge Project (20%) Laboratory Report (5%) Final exam (50%)
2	An introduction to professional work in technologically-focused industries	Lectures, group-based problem solving tutorials, group discussions, and laboratory sessions.	Quizzes (20%) EWB Challenge Reports (65%) EWB Challenge Presentations (15%)
3	An introduction into engineering design and communication through the use of computer aided design (CAD) software.	Lectures, class discussions, class software demonstrations, computer-based tutorials.	Quizzes (20%) Group Project (25%) Class test (20%) Final Exam (35%)

For course 1, students worked in groups to design and build a spaghetti bridge that can support a 2 kg car driving across it 10 times without damage. In course 2, students undertook design projects that were facilitated by the organization Engineers Without Borders (EWB). Students were asked to identify problems such as water supply, sanitation and hygiene, waste management, and climate change faced by communities in a developing country. Then, students were asked to design solutions to the problems identified. In course 3, students worked in groups on collaborative design projects that involved the utilization of CAD software and the production of prototypes using a 3D printer.

A total of 294 students were enrolled in course 1 and course 2, respectively, while 187 students were enrolled in course 3. Of these, 103 students were enrolled all three courses. On average, 65% of students were Australian citizens, 30% were international students, and 5% were New Zealand citizens and permanent residents.

3.2 Data Collection

The study's approach comprised both qualitative and quantitative research methods (Creswell, 2009). Two rounds of survey, which provided quantitative or numeric description of trends, attitudes and opinions of students were distributed during the two-hour classes that the students attended. Student feedback was gathered through two anonymous surveys, one conducted at mid-semester during week 5, and the second conducted at the end of the semester in week 11. The first survey was designed as a pre-test; the end-semester survey was designed as a post-test. Each survey took five to ten minutes to complete.

A questionnaire for both pre- and post-test surveys was designed to evaluate students' perception of collaborative work, skills, attitudes and learning development. Most questions required students to select an option on five-point Likert scales from 1 to 5 (Allen & Seaman, 2007; Boone & Boone, 2012), indicating a level of agreement with or a frequency related to a corresponding statement, such as 1 = strongly disagree and 5 = strongly agree. Table 2 lists an example of a Likert scale, with questions related to the students' engagement and their perceived benefits of virtual CAE tools. These were the questions used in the survey.

One short open-ended question was included at the end of the survey to allow respondents to provide feedback in their own words. The survey was anonymous, i.e., a student was not required to provide any identifiable information in order to complete the survey. Students were also invited to participate in focus group discussions. These discussions explored students' perceptions of the advantages and disadvantages of the different modes in collaboration and peer learning they had experienced, and how they believed these differences had affected their skills and knowledge development.

Table 2 Scaled Responses and Example Survey Questions

Likert Scales				
1	2	3	4	5
Never	Rarely	Sometimes	Often	Always
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Sample Questions				
Q2.1 Contributed to group discussion				
Q2.2 Worked with group members to complete the project				
Q2.3 Shared or taught class materials to group members				
Q2.4 Spend my time and effort on the assignment/project				
Q3.2 Do you agree the use of virtual CAE environment meets your personal learning preference?				
Q4.2 The virtual CAE provide me with an environment that maximize my learning outcome.				

Data collection was completed in Semester 1 2015. We analyzed participants' responses to the questionnaire items using standard statistical means and deviations, which were considered to be appropriate (Boone & Boone, 2012; Carifio & Perla, 2008). Accordingly, we used the parametric statistics, such as one-way ANOVA (analysis of variance) test and paired sample t-test to find any significant differences between groups. The level of statistical significance was < 0.05.

4. Findings

4.1 Anonymous Student Feedback

A total of 31 students responded to the mid-semester survey (six females and 25 males), with more than 70% were aged from 18 to 20 years. The end-semester survey had a better response rate with 84 respondents (17 females and 67 males), with more than 80% were aged from 18 to 20 years.

Figure 1 shows the responses of students in the two surveys relating to their team discussion and engagement, when participating in group projects, comparing traditional face-to-face and virtual CAE environments. In the mid-semester survey, more than 40% of respondents indicated that they 'always' contributed to group discussions in the face-to-face and virtual CAE design project. However, in end-semester the number of respondents decline to about 30% when asked the same question (Q2.1). In the mid-semester survey, more than 80% of students indicated that they "often" or "always" work in groups to complete the project (Q2.2) in face-to-face project as compared to about 75% in the virtual CAE project. Similarly, 60% of respondents "often" or "always" support their team members by sharing their learning materials (Q2.3) in the face-to-face project. In addition, in the mid-semester survey the majority of students indicated that they have devoted time and effort to complete the project (Q2.4) in the face-to-face project, while the percentage was slightly lower in the virtual CAE project.

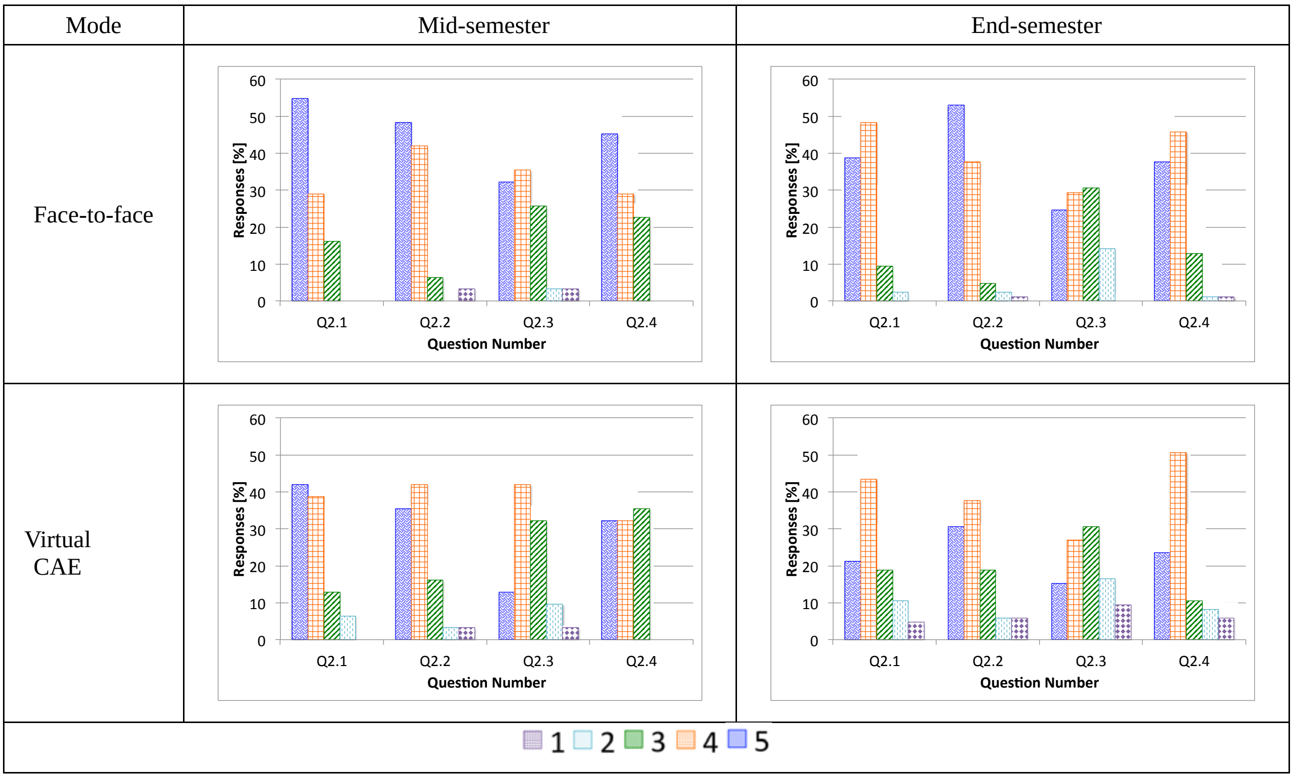

Figure 1 Comparison of Student Engagement and Collaborative Work in Traditional Face-to-face and Virtual CAE Environment in Mid-semester and End-semester Surveys

4.2 Student Perceptions

Students were also asked to rate their perceptions on how easy it was to use the virtual environment for their collaborative projects, and how their learning efficiency, communication with peers and professional skills had developed in the virtual environment. The results of student responses in mid-semester (Week 5) and end-semester (Week 11) surveys are summarized in Table 3.

Table 3 Student Perceptions of the Collaborative Learning Using the CAE Virtual Platform

No	Questions Item	Baseline (Week 5)		Follow-up (Week 11)		
		Mean	Median	Mean	Median	Mean change
1	Ease of use	3.655	4	2.975	3	-0.6802***
2	Learning efficiency	3.667	4	3.226	3	-0.4405**
3	Professional development	3.517	4	3.190	3	-0.3270*
4	Communication	3.567	4	3.157	3	-0.4100*

A negative value indicates decline in agreed level.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Overall, students gave a very positive feedback on both face-to-face and virtual collaborative projects. They contributed more often (combining "always" and "often") to group discussions and worked with group members to complete the project. However, the decline in agreed levels (agreed or strongly agreed responses) on the student cohort's overall perception and learning experience can be considered an indication that the collaborative design via CAE environment may not provide them the experience they were expecting.

4.3 Student Perceived Benefit

Comparisons were made between the answers in Questions 3.2 and 4.2 to evaluate students' perceived benefits of virtual CAE tools related to their personal learning preferences and outcomes (Figure 2). Nearly half of the respondents found that the virtual CAE tools improved their learning outcomes (Q4.2). However, the percentage of students strongly agreeing that the virtual CAE tools met their learning preferences and maximized their learning outcomes decreased between mid-semester and end-semester. A one-way ANOVA test was conducted to test the change in students' perceived benefits of the CAE tool. The test proved that a significant difference did not exist between mid-semester and end-semester surveys for questions 3.2 ($F = 2.95$, $DF = 1.115$ & $P > 0.05$) and 4.2 ($F = 0.38$, $DF = 1.115$ & $P > 0.5$).

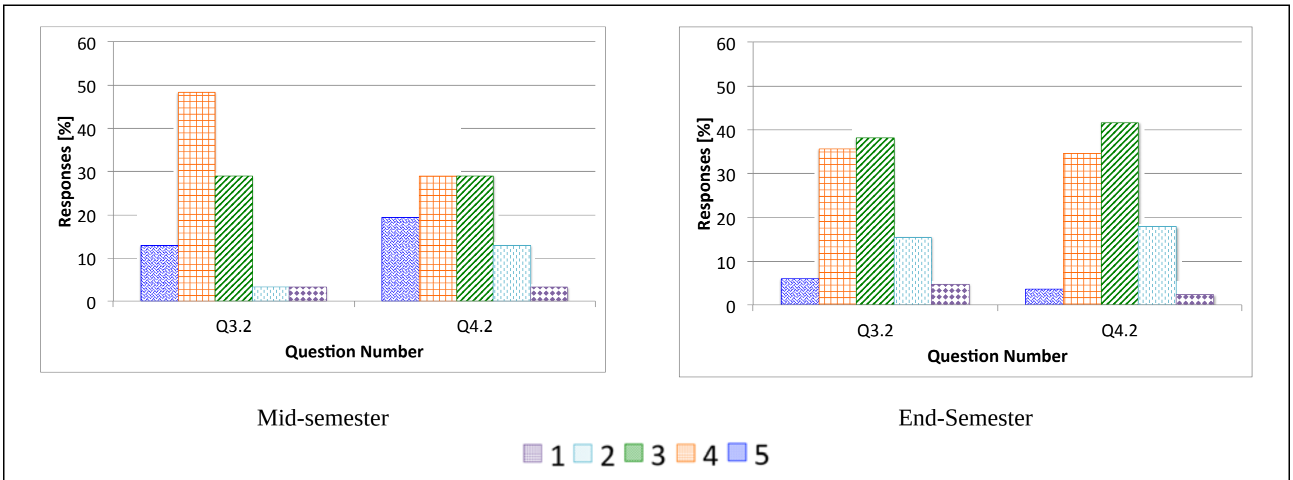

Figure 2 Students' Perceived Benefit of the Virtual CAE Tool related to Their Learning Preference and Outcome

4.4 Student Course Experience Survey

At the end of the semester, students were invited to provide their feedback on (1) what was the best aspect of this course and (2) what aspects of the course were in most need of improvement. Some common themes emerged from the surveys and are listed in Table 4.

For the face-to-face projects, student reported largely positive experiences with the EWB and Spaghetti bridge projects, where they enjoyed the teamwork with others. In the CAD course, students enjoyed that they were able to interact and create 3D objects within the virtual environment and perform 3D printing of the objects. The analysis also identified specific areas for improvement in the courses. Common recurrent feedback related to allowing more and greater time for tutorial sessions. Lecture format as well as technological issues related to accessibility and slow network connections also did not meet students' expectations.

Table 4 Common Feedback from Student Survey

Course	Best Aspect	Need Improvement
Face-to-face	Group projects (EWB and Spaghetti projects) Teamwork Tutorial sessions	More tutorials and longer period Lectures and content Online assessments
Virtual CAE	Learning and using a new software 3D printing Tutorial sessions	Technological issues with computers and Software More tutorials Feedback on assessment tasks

Some of the students' comments included:

Group work has been a challenge, e.g., managing the different levels of English skills among group members. International students struggled to write comprehensible pieces.

Another student commented:

….communication between individual students [need of improvement]

The challenge for many students was that about 30% of their peers are international students with differing levels of English language skills. The language skills (written and oral) related issues presented above are across both face-to-face and virtual collaboration groups. Hence, better awareness of the different proficiency levels in English written skills among students may have a positive effect on their learning outcomes.

In contrast, one student appreciated the help and support from team members to improve the language skills. He commented:

> Working in groups that helps international students like me to practice and improve my English.

Clearly, communication, either oral or written, needs special attention to allow for better communication between team members, and to assist learning and mutual motivation for others in the collaborative environment.

5. Discussion

Collaborative learning activities have long been included in the undergraduate curricula through project-based learning. In a collaborative project, students need to access different sources, such as Internet and library resources, to exchange ideas; discuss and solve problems; and complete projects together. In addition, students in a design course need to access CAE software to perform design creation and modification. The key purpose of this study was to evaluate the effectiveness of managing collaborative design projects, via face-to-face or virtual CAE environment, among first-year engineering students and how their engagement with the virtual tools affected their knowledge, skills and learning outcomes.

Results from the anonymous student surveys (Figure 1) indicated that, by and large, students had a positive attitude to teamwork and engaged with all team members working towards the completion of the design projects. For the first five weeks into the semester, most students actively participated in group discussions through face-to-face activities and through interactions in the virtual platform. They clearly tried to become acquainted with their team members and to build a sense of belonging within the group (Yeh, 2010). The use of collaborative platforms also encourages and enables students to work together and share information (Rodriguez-Donaire et al., 2010). However, students did not respond as positively in the end-semester survey compared with mid-semester. By the end of the semester, students provided more positive responses to the face-to-face collaboration than to the virtual collaboration. These may be due to technical issues, such as unstable network, and slow computer, as well as relatively in experience of student in using the CAD tools required them to put extra effort and time to familiarize with the virtual environment.

Fewer than half of the students agreed that the virtual environment allowed them to communicate and collaborate better with their peers. This is because most of them found the use of the virtual platform challenging, particularly because they did not have any prior knowledge of the tool and the technology. Some students stated that, although they had enjoyed the opportunity of learning the new software and using the technology offered in the virtual environment, they had to devote more time and extra practice to that in order to get the most out of the virtual environment. Previous studies (Karpova et al., 2009; Wilson et al., 2006) have indicated that in a purely virtual collaboration students have to overcome more obstacles than when using a face-to-face approach. Lee and Kim (2005) also highlighted that virtual environments "…offer learner[s] relatively few chances to solve problems through face-to-face interactions compared to traditional classroom, thereby making it difficult for learners to develop a shared understanding …" (p. 273). In order to improve student participation, group discussions, and problem solving, Yeh (2010) has suggested educators need to have a good blend of virtual and face-to-face collaborative learning because of their complementarity. This suggests that we need to identify which blended learning mode can be further developed and improved to create a more effective pedagogy for virtual collaborative projects.

Students indicated that collaborative design project could often be problematic in both face-to-face and virtual environments when a high fraction of international students (about 30%) have different levels of English proficiency. In an earlier study, the authors (Pang et al., 2015) also found that good communication between students can often be a problem when the text is not made explicit within the virtual environment. Misunderstandings should be addressed quickly as these might have negative effects on the student learning process.

It is important to note that most of the students are transitioning from high school to first-year university. The transition from high school to university can be extremely challenging for many students. They seem to find lecture formats are a less conducive way to learn compared with workshops, tutorials and group work. However, according to Akili (2010) project based learning is also a foreign experience through which the student must be guided: "When students are exposed to [project based learning] for the first time, they must be guided, prepared and motivated. It is not fair to expect students to readily have the skills, particularly when they have been exposed solely to traditional classroom environment" (p. 6). There is a particular challenge, then, in developing a coherent course/subject structure for a first year class because of their lack of experience with the traditional "lecture" format of University teaching and the more experiential collaborative form of teaching which also occurs in higher education.

Currently, the virtual CAE platform requires students to connect to a mainframe server that allows them access to the design software as well as 3D design data. When our survey was conducted, students could only access to the software and 3D data server on the university campus. Due to hardware compatibility issues, there were technical interruptions when students connected and transmitted data to the server. Hence, they indicated that the use of virtual CAE environment was extremely challenging, particularly with unstable Internet connections, limited access to computer labs and no remote access to the virtual platform.

Despite the technical issues, the majority of students enjoyed the practical sessions and the 3D printing of the prototype. During the practical sessions, students had hands-on experience in using and developing their technical skills on the CAD tools. They could also apply their design principles, such as design constraints, part and assembly design, and fits and tolerances, to develop 3D design models. This is in agreement with Jou and Wang's (2013) recommendation that practical training is key element that brings imagination and creativity to fruition within the virtual learning environment.

6. Conclusion and Implications

More and more universities are gaining the facility to use virtual learning platforms to deliver a 3D user experiences that allow students to perform collaborative design. Students can connect with peers, access data and generate solutions in a single, intuitive, virtual environment. It is essential that students develop skills in virtual collaboration that maximizes the value and quality of their learning experiences and outcomes by ensuring that these experiences are as close to the real-world activity as possible.

This study provides further insight into the benefits and pitfalls of virtual and face-to-face collaborative teaching and learning. On the whole, students provided positive feedback on virtual and face-to-face collaborative projects, where they could participate in team discussions and support one another. However, students require time and effort to develop these skills to use the virtual CAE tools, and many of them have difficulties at first when coping with the new tools. As noted in the survey feedback, there are potential misconceptions of the technological difficulties of using virtual platforms that need to be addressed. The findings on students from diverse backgrounds, experience and expectations highlight the differences in English language proficiency between local and international students, which can sometimes cause communication breakdowns and misunderstanding. Cross-cultural communication skills between team members, such as provide constructive feedback and clarity of communication, need to be carefully considered especially in collaborative project teams.

The findings of this study provide insights for educators to assist them in adopting a suitable style of teaching to improve student learning experiences, as well as insights to improve educational pedagogy in: (i) the use of virtual CAE tools; (ii) more effective project-based learning; and (iii) the use of virtual environments for collaborative design work.

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