Practice and Evidence of Scholarship of Teaching and Learning in Higher Education
Vol. 15, No. 1, December 2021, pp. 53-77

Authentic learning activities in engineering design course: What works well to cultivate engineers Australia's professional attributes?

Toh Yen Pang *
School of Engineering
RMIT University, Australia
tohyen.pang@rmit.edu.au

Alex Kootsookos
School of Engineering
RMIT University, Australia
alex.kootsookos@rmit.edu.au

Abstract

Authentic learning activities can help learners integrate knowledge, skills and attitudes necessary for effective task performance similar to those they may encounter in the workplace. We developed a teaching and learning model that was connected and relevant to the students' future workplaces with the goal of building authentic learning and assessment into a computer-aided design (CAD) course. New authentic elements such as project-based learning (PBL), electronic assessment, 3D printing and peer assessment were added progressively to cultivate life-long learning skills. This study was conducted to determine how the authentic learning activities and assessment methods influenced the overall course satisfaction and experiences of authentic learning among first-year undergraduate students studying the CAD course as part of their engineering degrees. Annual cohorts from Semester 1, 2014 to 2019 were included in this study. A qualitative research design, involving multiple data collection points via an online questionnaire, was used in this study. Content analysis was used to summarise students' feedback and determine themes used to inform improvements needed. The results of this study suggest that the authentic learning activities had a positive impact on students' learning outcomes and overall satisfaction with the course. A

*Corresponding Author

ISSN 1750-8428 (online) www.pestlhe.org

majority of students believed that the learning activities in the course embraced a hands-on approach that was closely associated with real-life workplace situations and they were able to apply their knowledge to support self-directed and independent learning.

Keywords: Authentic learning, assessment, engineering, project-based learning (PBL), computer-aided design

Introduction

We educators need to allow our students to acquire skills that will enable them to develop their careers in an increasingly complex and fast-changing society and global economy. A number of studies and reports have emerged over the past decade that identify the '21st-century skills' students need to succeed in the global labour market (Griffin et al., 2012; Larson & Miller, 2011; Stuart et al., 2012; van Laar et al., 2017). Such skills include expert thinking and problem solving, teamwork, complex communication, creativity and innovation, and digital skills (Afreen & David, 2017; Fletcher et al., 2017; Levy & Murnane, 2012; Stuart et al., 2012; The Economist, 2015). Graduates who are able to transfer the 21st-century skills to the workplace will distinguish themselves and have better career opportunities than those who only acquire the foundational skills such reading, writing, mathematics and language (Levy & Murnane, 2012). Attention, therefore, must be directed to how well educational programs can support and enable students to align their learning with real issues in the world of practice.

The term 'authentic learning' is used as a common element in learning design to describe how students develop robust knowledge that is transferrable to professional practice in a fast-changing world (Lombardi, 2007; Roach et al., 2018). As noted by educational researchers, the elements of authentic learning typically focus on real-world, problem-based, interdisciplinary and complex problems, which require students to work collaboratively with others and apply their theoretical knowledge to create innovative practical solutions. More importantly, authentic learning activities provide students with opportunities to express their ideas and reasoning, as well as reflect on their learning (Herrington, 2006; Herrington & Oliver, 2000; Herrington, Parker et al., 2014; Herrington, Reeves et al., 2014; Latham & Ewing, 2018; Lombardi, 2007; Riley & Stern, 1998;

Simpson, 2016; Vu & Dall'Alba, 2014; Wiewiora & Kowalkiewicz, 2019). Authentic learning also aims to equip students with essential skills that they require for life beyond study. According to van Merriënboer and Brand-Gruwel: 'Authentic learning tasks help learners to integrate the knowledge, skills and attitudes necessary for effective task performance, and eventually enables them to transfer what is learned to their daily life or work settings' (van Merriënboer & Brand-Gruwel, 2005: 414).

When thoughtfully designed, authentic learning can encourage students to engage in active learning tasks and subsequently achieve improved outcomes. For example, Herrington (2006: 3164) asserts, 'authentic learning designs have the potential to improve student engagement and educational outcomes'. In a recent study, Simpson (2016) introduced authentic learning methods into a Master's Degree in a Business Administration subject (Accounting and Finance for Decision Making) by changing the teaching and assessment methods. The results of this intervention were better pass rates and a more enjoyable and satisfying learning environment for the students.

A number of studies have reported on project-based learning (PBL) as a form of authentic learning. The realist context of PBL and its multi-faceted possibilities help each student to develop the ability to become an independent problem solver, a self-directed learner and an effective team player. It also challenges a learner to think in the same way as professionals working in real-world contexts (Grant, 2011; Hung, 2015; Jacobson, 2015; Savery, 2006). In addition to PBL, authentic assessment that promotes life-long learning has been identified as a key element of authenticity (Herrington, 2006; Hursen, 2016; Simpson, 2016; Villarroel et al., 2018). As described by Villarroel and colleagues:

'Authentic assessment aims to replicate the tasks and performance standards typically found in the world of work, and has been found to have a positive impact on student learning, autonomy, motivation, self-regulation and metacognition; abilities highly related to employability' (Villarroel et al., 2018: 840). Similarly, as reported by Raymond et al. (2013: 471): 'Authentic assessment activities are designed to mimic the complexity of "real world" situations that students may encounter in professional life. Authentic assessment activities require students to demonstrate the same competencies, or combinations of knowledge, skills and attitudes that they need to apply in a similar situation in the professional workplace'. In a review article, Struyven et. al. (2005) reported that different types of assessments and students' perceptions of assessment

significantly influenced their approaches to learning and studying. The influence could be either positive or negative, depending on the evaluation tasks, the context, the workload demands, and whether the assessments were intellectually challenging so that students were allowed to apply their knowledge to realistic contexts. Authentic assessments also need to provide students with the opportunity to demonstrate how their performance has been informed by their learning and acquired knowledge (Murphy et al., 2017; Struyven et al., 2005).

The purpose of this paper is to determine the impact of instructional activities, which were designed for authenticity, on the students' perceived satisfaction in and their attitudes toward professional and personal attribute development (as outlined in the Stage 1 Competency Standard for Professional Engineers mandated by Engineers Australia (Engineers Australia, 2013)). For this purpose, we addressed the following research questions:

1. Is student satisfaction affected by perceived authenticity in assessments?
2. Are the students' perceptions of assessments and learning activities congruent with the commonly understood characteristics of authenticity?
3. How have the authentic learning activities, especially PBL and collaborative learning, helped students' progress in developing key transferable skills and workplace readiness?

Methodology

An online survey where students responded to a five-point Likert scale was used to analyse their experience for the CAD course. A qualitative research design involving a number of data collection methods, comprising curriculum design and assessment tasks and new instructional activities, was used in this study. Students' comments were reviewed to identify key themes for further analysis.

Curriculum design and assessment tasks

This course provided an introduction to the principles and methods of engineering design and emphasised the critical role of graphic communication. Students' learning activities

were supported by computer-based tutorials and they used CAD software to generate computer models and technical drawings with reference to the Australian Standard for technical drawing (Australian Standard, 1992).

At the beginning of the academic year of 2014, we took the decision to revitalise the course delivery and assessment tasks to ensure that the elements of authenticity were demonstrated by the assessments. With the goal of building authentic learning and assessment into the course, we carefully developed a teaching and learning model that was connected and relevant to the workplace context, to ensure the course contributed to the program learning outcomes (Figure 1). We also ensured that once students graduated with their degrees, they could satisfy the Stage 1 Competency Standard for Professional Engineers when they enter the labour market. As depicted in Figure 1, the assessment design, the nature of authentic tasks, the assessment criteria and the feedback are engaged in an iterative process, wherein we reviewed and refined our approach to introduce more complex learning initiatives over time. We also constantly evaluated the model, drawing upon our experience to determine the next steps for improvement.

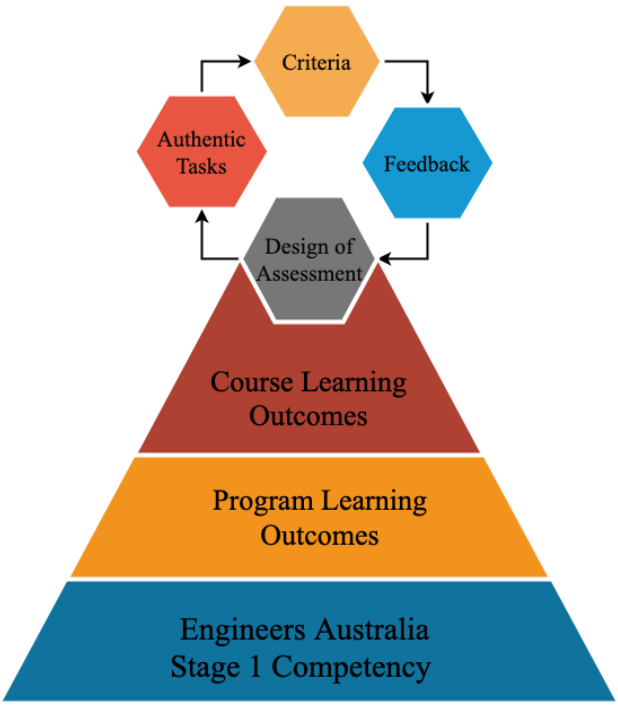


Figure 1. Teaching and learning model used to develop authentic activities and assessment tasks that contribute to students' learning outcomes and competencies mandated by Engineers Australia.

Authentic assessment should also be associated with meaningful feedback that provides information on performance and measures changes in learners' knowledge, skills and abilities. The criteria for assessing students' work also needs to reflect the attributes of authenticity (Ackerman & Gross, 2010; Bates et al., 2013; Gamlem & Smith, 2013; Molloy & Boud, 2014; Shute & Kim, 2014).

We embarked on an early adoption of Computer-Aided Three-dimensional Interactive Application version 6 (CATIA V6)—an industry standard software for engineers to manage design and engineering activities—to provide a digital environment to promote collaboration between students. Based on the experience of early CATIA V6 adopters, we embedded PBL into authentic learning activities to create more opportunities for students to interact with peers and teaching staff.

The first step was to alter the traditional assessment by creating a test that would meet criteria for authentic learning. As a result, all assessment was revised and redesigned to be computer-based (Nguyen et al., 2017; Pang et al., 2015; Pang et al., 2017; Wibowo et al., 2016) and comprised both individual and group assignments. We introduced real-world group projects wherein students were encouraged to form diverse groups (i.e. members from different ethnicities, backgrounds, languages, nationalities etc.) to collaborate online through the digital platform for their group project. Student projects were based on the complete engineering design process: both the initial stages where the students were tasked with addressing a high-level design problem by exploring user needs; and research and design ideation. Then, students designed a detailed solution at the technical level. They were also required to consider how to protect the intellectual property of the design and/or commercialise the product.

New instructional activities

Students were required to attend a weekly two-hour computer laboratory session, during which academic staff worked with them to solve their engineering problems. Staff also provided students with real-time feedback on their problem-solving abilities. New authentic elements, described below, were added by the lead author as the course progressed. The new authentic elements were specifically aimed at improving students' knowledge and transferable skills (problem solving, teamwork, communication, creativity and innovation, and digital skills).

1. In 2014, PBL group projects were introduced, starting in week 1 of the semester. Each group was required to submit a final report in week 12 as part of the assessment, and computer-based assessments were introduced to replace the traditional paper-based assessment;
2. In 2015, students were introduced to additive manufacturing (3D printing) technology and they were required to 3D print their final design prototypes;
3. In 2017, peer assessment for collaborative design projects was implemented through the use of 'Spark^{PLUS}'—a web-based self and peer assessment tool (Ackerman & Gross, 2010; Bates et al., 2013; Gamlem & Smith, 2013).

Participants

This study took place at RMIT University, Melbourne, Australia, between 2014 and 2019. This study included first-year undergraduate students studying aerospace, mechanical, automotive, mechatronics, and sustainable energy engineering degrees in Semester 1, in which students take CAD as one of their core courses.

Data collection and analysis

A course-experience survey (CES) was carried out online between weeks nine to twelve to provide students with the opportunity to offer feedback on the course, and to improve the learning quality and experience for future cohorts. The survey questions were focused on perceived teaching quality and the students' experience in the course. They were asked in seven opinion-rating questions to select one option from a five-point Likert scale, coded from 1 = 'strongly disagree' to 5 = 'strongly agree'. All items were worded positively, so that higher scores indicated greater student satisfaction. Two short, open-ended questions were included at the end of the survey to allow students to offer feedback on what worked well and what needed improvement in the course. In addition to the seven questions on the teaching quality and the students' experience, we also added some questions related to skills development in the 2014, 2018 and 2019 CES.

For the group project, students were asked to provide a statement detailing their individual contributions to the project (both to the report and the design process) and some reflection on group processes. Content analysis was used to summarise both the students' feedback and reflections to determine the improvements needed and the

perceived authenticity of the assessment and learning activities (Forman & Damschroder, 2007; Wang et al., 2012).

Results

For this study, from 2014 to 2019, we initiated an ongoing redevelopment syllabus for a semester-long CAD course to improve engineering design skills among students. Hence, we are reporting on six data points in this section. Authentic learning and assessments methods were used wherever appropriate in order to enhance key transferable professional practice skills from the classroom to the workplace.

The results of the anonymous online surveys are reported here in terms of the percentage of students who agreed with the statements of the survey. The open-ended questions, which required the students to comment on the best aspects and any major concerns about the course, as well as their reflections on the group project and report, were analysed for their content to develop key themes and the relative importance of each.

Table 1. Student cohorts enrolled in the CAD course and response rates

Year	2014	2015	2016	2017	2018	2019	Mean
% Male	84.5%	89.3%	86.4%	87.8%	91.9%	90.8%	88.5%
% Female	15.5%	10.7%	13.6%	12.3%	8.1%	9.2%	11.6%
% Local students	68.7%	66.8%	68.2%	72.2%	77%	79.5%	72.1%
% International students	31.3%	33.2%	31.2%	27.8%	23%	21.5%	27.8%
Response rate (%)	64.5%	47.3%	49.5%	73.9%	50.3%	65.9%	58.6%
No. of students	265	187	198	180	161	185	196

Participants and response rate

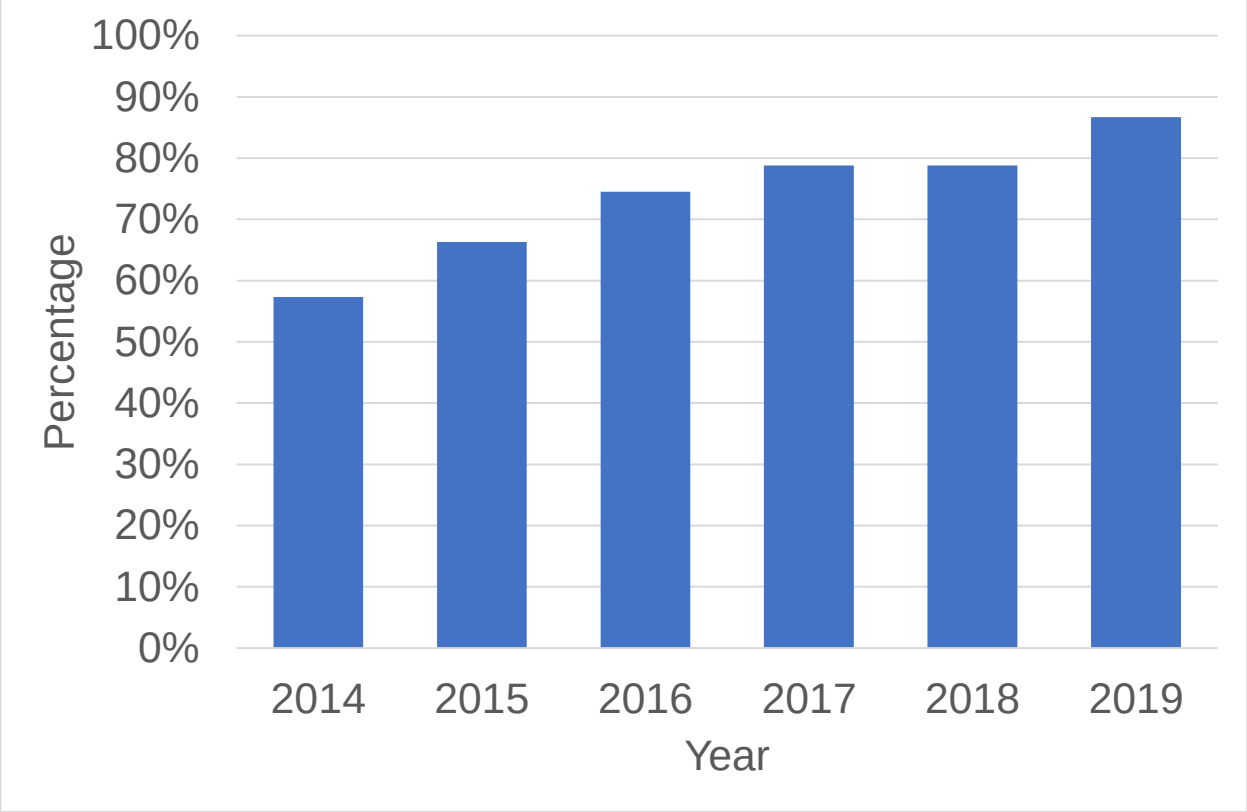
From 2014 to 2019, a total of 1,176 students enrolled in the CAD course, with an average of 196 students per semester. Generally, more male students enrol in engineering

degrees and an average of 88% (over six years) of students in the course were male. An average of 28% (over six years) of students were international students (see Table 1). The overall response rate was 58% (averaged over six years), which was adequate for this analysis.

Student satisfaction

When assessing whether the teaching approach was effective and whether students were satisfied with the quality of the course, we found their overall satisfaction with the CAD course continued to improve from 2014 to 2019 (Figure 2).

Figure 2. Students' perceived satisfaction of their learning quality for the CAD course.



As the new authentic learning activities were progressively introduced to the course, the findings suggest that authentic learning had a positive impact on the student success in learning and developing CAD skills to create 3D models and construct prototypes and in

making recommendations to improve product efficiency. The students' overall satisfaction also improved over time (Figure 2).

Authentic elements

Second, we now discuss the content analysis undertaken to: (1) determine if the students recognised the authenticity of the assessment and learning activities; (2) discover any major concerns that the students had; and (3) make note of any unexpected responses. Table 2 summarises the students' opinions of the CAD course that reflected the elements of an authentic learning approach.

Table 2. Students' responses on the CAD course related to the elements of authentic learning

Authentic elements	*The quotation in each section below is an example of the students' responses.* Beneath this, in each section, is our thematic conclusion from the content analysis.
Real-world relevance	*'Different to other subjects, lots of hands-on things to do and you can actually use this in your career'* Students found that the activities for the course are relevant to real world application; reflects that the knowledge gained can be applied in future career.
An ill-defined problem	*'CATIA — learning how to use this program at its basic level has been interesting and challenging. It helped me to constantly develop my understanding of the engineering environment.'* Learners must identify their own unique tasks and sub-tasks in order to complete the major task
Sustained investigation	*'The course is challenging, and it is the most important subject we, as engineers, have to catch up. I am not good on hands with computer designing tools clicking but there are parts I always have the chance to satisfy what I could only understand. It is just practical which I like it, although it is not easy to remember the technique and steps to fully finish the product or parts. Overall, it is progressive*

	course with hard work effort to put it and that is something I am still working on it.' Students agreed that the learning activities provided meaningful experience such as learning outside the classroom, and the design aspect tasks are complex and challenging.
Multiple roles and perspectives	*'Learning about a program that allows you to expand on your own skills even after completing the course makes it incredibly useful and also opens up another side of engineering. It was able to give me a break from the theory and mathematical heavy based subjects, which was brilliant for a visual and design-based learner.'* The task affords learners the opportunity to examine the problem from a variety of theoretical and practical perspectives. Resources may be theoretical or practical and may require learners to distinguish useful information from irrelevant information.
Collaboration	*'The different opportunities to work on our CAD skills as well as being able to work in groups to learn what it takes to design something together'* Students found there is opportunity for them to collaborate with others and use engineering design processes and industry design software to provide solution to group projects.
Reflection	*In reflection, the team should have had more meetings in person to discuss the exact expectations of the work to be completed and we should be set deadlines earlier to complete the work in a more gradual fashion. Group members should have had to do work collectively to assist each other and enhance the quality of work rather than just assigning work and that's the basic purpose of making groups.* Students provided reflection on their own learning process and experience as well as with their peers, where they collectively considering actions for further improvement and to achieve high quality outcomes.
An interdisciplinary perspective	*'The immediate practicality of this course. Hence i can use the skills from this course in my other courses as well as personally in my own time.'*

	Students found that the skills and knowledge developed in this course can be applied to other courses.
Authentic assessment	*'I liked the idea of the innovative based assignment that was issued, allowing us to show creativity. I also liked the practical classes each week that re-enforced the knowledge learnt in the lectures.'* Assessment of activities is seamlessly integrated into the major task in a manner that reflects real world assessment, rather than a separate artificial assessment removed from the nature of the task.
Polished products	*'Learning one of the basic aspects of engineering through this course, as CAD is one of the most used software in the engineer life. One if the good part was practical experience while building smartphone holder and then 3d printing it.'* The project allows students to create their own products using the 3D printing techniques.
Diverse outcomes	*'Early during this process, we noticed structural ambiguity and the presence of plausible, detrimental failure of a pull pin connection. During the next Skype meeting, we discussed extensively and agreed upon removing the pull pin connection approach from our design in favour of the mounting principals of a DLSR camera lens.'* Instead of coming up with a single solution, students managed to use the learning activities to develop plausible solutions to solve issues to hand.

Findings from the content analysis indicated that our approach managed to achieve all ten key authentic elements (Table 2). From the students' feedback, we are convinced that the authentic teaching and learning approach we adopted was valued by them. Students also noted that the course fostered collaboration, allowing them to work and learn from others, and to use knowledge gained to create solutions and products that were truly useful.

Project-based learning and group projects

We included a question in the survey to assess if the group project in the new curriculum helped to develop students' abilities to work collaboratively as team members in the design activities and to develop interpersonal communication skills. In 2014, 61% of the

students strongly agreed that the group project helped them cultivate collaborative team skills and improve interpersonal skills. The students' perception of the usefulness of these learning activities and assessments increased in the following year to 75% and 78% in 2018 and 2019, respectively. Students indicated that not only could they collaborate with peers to cultivate a team spirit to achieve a common goal, but that they also valued the new learning approach because they learnt how to help each other solve problems. Here are some examples of their comments:

> *The group project presents an interesting opportunity to collaborate with others and experiment with the design process and CATIA.*

> *The group project as you are able to share your knowledge of CATIA and therefore teach and learn from others.*

> *Upon reflection of the project, it was felt that the project allowed us to successfully practice both working as a group and the engineering process, in addition to allowing us to use the theoretical and practical skills with respect to the use of CAD (Computer aided drawing) in a real world setting. Furthermore, it allowed us as a group to practice the problem-solving methodology that's so prominent in the engineering industry.*

Computer-based assessment or e-assessment

In the 2014 online survey, we asked whether they found the assessments in the course challenging. Ninety percent of the students indicated that they strongly agreed, especially when they were under pressure to complete the task within the allocated time limit. One student commented:

> *Assessment tasks. Although they need to be challenging, they are extremely difficult especially under limited time and hence does not adequately show a student's ability and knowledge acquired during the course.*

The findings from the students' responses indicated that they valued the balance of laboratory learning activities they had to prepare them for the e-assessments. One student commented:

> *The amount of class time dedicated to hands on software learning was great, and the assessment quizzes were great fun.*

Despite students being familiar with e-assessments, the results in this study indicated that some students experienced concerns with e-assessments that are set to a limited time. It was also clear that, when facing complex problems, some students could not assess the optimal amount of time spent on one question before moving on to the next, in order to complete the entire assessment on time:

> *…do not set the expectation too high given that it is a first-year course that might increase the failure rate of this course, but have an achievable task in a given timeframe that is doable and could help students gain self-confidence. If the assessments are hard, increase the timeframe of doing the task especially on quiz 3 and the final exam...*

Anecdotally, we found that students preferred the progressive assessment approach, in which easier and familiar assessment tasks were provided to them early in the semester, as formative assessment. They could then leverage this opportunity and compensate for poor performance in any assessment by constantly improving their skills.

3D printing

Additive manufacturing (3D printing) was introduced in 2015: hence, findings reported in this section on pertain to five data points only. Twenty-one percent of students who responded to the online survey indicated that the 3D printing was an interesting and useful experience. We continued to monitor student responses from 2016 to 2019 and on average about 10% of the students indicated that 3D printing was the best aspect of the course and most useful in helping them to identify any design flaws:

> *3D prototype would be able to demonstrate flaws in the design allowing us to make changes to the 3D model where required and refine the product to make it an ideal solution.*

> *3D printing is not without its flaws, but it was a really useful tool in the design process and being able to quickly prototype and examine the final product assisted us in assessing the design's quality.*

> *'The project is what makes this course interesting as we have the opportunity to apply our knowledge into designing and creating our project in our own ways.'*

While most students valued the 3D printing, some found that the limited availability of printers affected their overall learning experience. One student commented: 'Not enough printers to go around… Had print cancelled on my group three times without warning or explanation...'.

Peer assessment

Peer assessment was introduced to the students via a web-based self- and peer-assessment tool (Spark^{PLUS}). Here, we report on one data point in 2017. The 180 students in the 2017 cohort formed 45 project groups. All group members were invited to assess their peers based on four assessment criteria (attendance, contribution to good ideas, contribution to the success of the project, and quality of work). A total of 72.9% provided comments and reviews based on these criteria. In addition, 9.5% of the students indicated that Spark^{PLUS} was a good tool that enabled them to provide honest feedback and ensure that every member contributed significantly to the success of the project.

> *Yes. I liked that you can provide feedback to your team-mate. However, it would be good to have a section that you can comment in without that team member being able to see it.*

> *It's an excellent way to give feedback about what you honestly think of your group members and being forced to do it as part of assessment takes the weight off having to email course coordinator and possibly create a scenario.*

> *It's an opportunity to allow us to grade our peers, giving them a mark boost if they performed greatly, and a reduction in marks if they did poorly as a group member.*

Students' reflection on their skills development

The students' attitudes towards a greater independence and responsibility in controlling their learning activities was evidenced in their responses and reflections on the course activities. Students recognised the importance of good communication skills for a group to function effectively. They appreciated group efforts as they reflected on their experiences when engaging in the group tasks. They also commented that group tasks helped them to develop the skills applicable to the real world as well as expand their knowledge in another field:

> *Working in this team was a thoroughly enjoyable experience, as we were able to effectively communicate and delegate roles to each other. I was heavily involved throughout the initial stages of market research and problem defining. I also contributed to multiple initial rough sketches, as well as developing Dung's final design into a 3D CAD model for the initial prototype. I was also involved with the writing of multiple sections of the report, including the conclusion, the abstract, the introduction and the method. I learnt a lot about leveraging each other's strengths and ensuring all members felt willing to input. I hope to apply what I learnt in this subject (and more specifically this project) into the real work when designing new and exciting products - especially in the field of sustainability.*

Students also provided an overall statement on communication and reflected on the best approach to ensure group members adhered to a high standard and provided specific and concrete examples of respecting others' ideas and shared goals:

> *We had a variety of ways to keep track of the progress of the entire project; these included a Gantt chart, weekly meetings held mostly on Tuesday mornings where the contents of each meeting was recorded in a meeting's minutes. Each individual contributed evenly to the project and completed all tasks assigned to them within a timely manner and to a high standard… A strong point of the group was our communication. We had a Messenger Group chat, where we shared*

> *ideas, meeting times and places and other necessary information. We all respected each other's ideas for the design and were willing to explain our thoughts and ideas when a team member did not understand the concept; we also shared our honest opinions on ideas which assisted us in ensuring we all had the same common goal for the project and its end result.*

Key transferable skills and workplace readiness

Additional questions were added to the 2018 and 2019 surveys on professional practice skills. Hence, we report on only two data points in this section. When asked whether they had learned something in this course that better prepared them for employment, 99% of students indicated they strongly agreed and 83% indicated that the course developed their confidence to investigate new ideas.

In assessing if the content or activities of the course were delivered in a way that enabled the students to transfer their newly acquired knowledge to the workplace, several students indicated that the engineering design process, software and creativity skills would be useful in their work:

> *It is a very eye-opening course. Creative and you can easily see its workplace applications.*

> *Learning how to make ideas you come up with reality by designing it, and also the fact that the skill of CAD is extremely useful in the workforce.*

> *Very hands on. I enjoyed using CATIA. This course seems like it will be useful for my career. I learnt about a lot of aspects of engineering, such as design process and drawing.*

> *It's a very hands-on course in terms of computer use, having the knowledge to design parts using CATIA is a very noticeable skill when it comes to real life work.*

We evaluated student perceptions of the new learning activities to see if these helped them develop key transferable skills. Many students indicated they had developed higher

levels of creative design skills, were able to communicate more effectively, and help each other with solving problems. Students also indicated that they had developed new skills in using the industry software to create 3D models and key engineering design processes are which relevant to real work.

Discussion

This study investigated the impact of new instructional activities, which were designed for authenticity, on the development of first year students' professional and life-long learning skills. The redesigned course delivery and assessment task were valued by the students because they perceived both to involve real-world problems that mimic the complexity and challenges of professional engineers. The students also believed that the learning activities for the course embraced a hands-on approach and were closely associated with real-life workplace experience. They reported they were able to apply their knowledge to support self-directed and independent learning. Results from this study have therefore contributed to the understanding of authentic learning and assessment tools used in higher education.

More specifically, this study was innovative in its authentic learning approach. The group project was introduced as a PBL authentic learning device to enable both student group learning and individual skill development. For the PBL, we used the group technique to help students learn how to collaborate with other team members and how to function as an effective team member to help and share knowledge to achieve a common goal. The computer components (CATIA software and 3D printing) also equipped students with new skills and techniques to solve problems. In this way, we enabled students to acquire base level digital literacy skills that applicable to the workplace (Afreen & David, 2017; Fletcher et al., 2017; Stuart et al., 2012; The Economist, 2015; Levy & Murnane, 2012).

In the PBL activities, we asked students in groups to conduct collaborative investigations, create innovative solutions to real-world problems, and effectively communicate their solutions to others in the form of 3D models, technical drawings and physical prototypes. For this study, students were able to book and use 3D printers to fabricate prototypes, which helped them materialize their design ideas. The prototypes assisted students to explore their design solutions through visualization and physical manifestation. Our study

demonstrated that students not only utilized the prototypes to identify design flaws for improvements, but also improved creative and problems solving skills (Saorín et al., 2017).

While 3D printing has brought improvement to students' learning, its implications and sustainability should always be taken into account. This meant providing sufficient training to students on how to operate the printers, having sufficient printers for a large number of students, and managing a good booking system and time limits for each print session to minimize over-crowded laboratories. More importantly, students needed to be reminded that they should not waste material on creating useless products. As Fraumann et al. (2015) indicated, a failed design also forms part of learning in an innovation process. Hence, students were still encouraged to print their prototypes to provide learning benefits that could not be achieved with computer screen observation alone.

Secondly, the assessments tools help students to develop their professional and life-long learning skills. The assessments tools used in the study were not just simply measures of performance, but also reflective tasks that enable the students to think about themselves, and their peers, and also feedback into the course so that teaching staff can shift and change the course to make it more effective over time.

As the CAD course used an industry-standard software for engineers to create 3D designs, technical drawings and manage engineering activities, it was logical that students should be assessed using those technologies and that assessments should resemble the type of tasks engineers are expected to perform in a real workplace setting. The e-assessments were designed to align with the curriculum and were aimed at measuring and monitoring the students' progress, their achievements and their learning abilities. They offered a means for the students to learn how to solve complex tasks and provided more authentic interactive assessment options.

In order to avoid any online cheating, the e-assessments were conducted on campus in the computer laboratory and were invigilated by teaching staff. To limit students' ability to defraud the system, they were required to complete the assessments within a set time frame of between an hour and a half and two hours. However, this may have contributed to some of the stress associated with the time allowed for the assessment, especially for those who had varying abilities and levels of skills in managing their own learning and,

consequently struggled to complete the required assessment tasks within a given timeframe. To help ease their anxiety and enhance their confidence for the e-assessments, we provided tests and quiz samples from previous years, for students to practise, as well as step-by-step guidelines on how to attempt the e-assessments.

A reflection statement was integrated into the final report that the students submitted as part of their assessments. Students could decide to either provide a personal or team reflection in the final group report. The reflective component of the report was not just intended to teach students how to write a good reflective statement, but to encourage them to be aware of the importance of exploring their experiences to foster new understanding and to consider any actions required for improvement (Wiewiora & Kowalkiewicz, 2019).

Challenges and direction for improvements

The use of e-assessment involving complex problem-solving to allow students to engage in realistic real world tasks and tools has been reported elsewhere (Pang et al., 2017), but the introduction of e-assessment can be challenging due to technical issues such as an unstable networks, slow computers, screen resolution issues and hardware compatibility. Hence, e-assessments need to be properly and thoughtfully implemented to support student learning, and technological challenges need further research in order to optimise their use in the improvement of student learning.

The design group work assessment comprised a proposal, a presentation and a final report. Assessing a large number of group projects is labour-intensive and assessing teamwork performance, teamwork skills and group interactions while also evaluating individual contributions can be challenging. The high burden of marking led to some delays in providing feedback. We found that this delay in providing feedback and/or assessing students' work without any effective and detailed feedback resulted in complaints and reduced student satisfaction. As one student commented:

> *No feedback on any work [has] been received, neither has the format for grading. Therefore, it makes nearly impossible to improve when we cannot see our mistakes.*

It is important for students to receive timely feedback to help them make adjustments in and improve their work. For feedback to be effective, teaching staff learned that we need to view the feedback through the lens of the students to understand how it affects learning and supports student growth and development over time. Teaching staff also need to provide constructive comments and specify ways to improve and then allow students time and opportunities to work with the comments and subsequently improve their learning process. Future studies are therefore needed to develop metrics that allow for the assessment of individual students as well as group performance during collaborative group projects, while not increasing the workloads of teaching staff. In addition to this, simple feedback mechanisms also need to be trialled which can reduce the delay between assessment due dates and feedback to students.

The implementation of peer-assessment via the online platform involved some deft planning and extra administrative support. Strategies such as how to set up student groups and define assessment criteria, how to provide constant reminders to students to conduct their peer assessments and the continuous monitoring by teaching staff were all necessary for successful implementation of peer assessment in courses.

Students found that peer assessment was also a good way of ensuring each group member was awarded with an appropriate grade based on the individual's contribution. However, in order to avoid possible negative effects and a low score, students indicated that they would prefer to provide their feedback anonymously. This is a common concern and has been noted in other studies (Rotsaert et al., 2017).

Conclusions

Authentic learning tasks and assessments are important for educators to help students develop relevant literacy, communication and technical skills that are transferrable to the professional workplace. The CAD course reported in this study embarked on a new teaching and learning approach involving authentic learning that aimed to cultivate these skills. We began by assessing students' satisfaction with the course in 2014 and have been able to report on six years of findings in this report. We progressively introduced authentic learning activities to promote professional and personal attribute development. We subsequently added assessments of 3D printing, key transferable skills and peer

assessments, and have reported here on five, two and one data points for these added assessments respectively. These additions contributed to our growing understanding of students' experiences in the course.

Students regarded their learning activities and assessments in the course as authentic because such activities involved real-world problems and reflected the complexity and challenges facing professional engineers in the workplace. Overall, the results revealed that the authentic learning was positively related to students' satisfaction. Findings on the group work suggested that students found it very useful. They were able to communicate more effectively and help each other with solving problems, and enjoyed the opportunity to collaborate with peers to achieve common goals. The integration of a reflection statement into the final group report also had benefits. Results showed that PBL and collaborative learning especially helped develop students' confidence to investigate new ideas and enabled them to transfer their newly acquired knowledge progressively from the classroom to the workplace.

A limitation of this study lies in its limited generalizability to other higher education degrees. This study uses data from one first-year undergraduate CAD course during which students used computer software to create design and 3D models, then produce prototypes using 3D printing. That said, the study also has generalisable results on the value of collaborative learning and the effects of systematic reflection on learning that could be useful in other courses. Further research is needed to address the challenges faced in using e-assessments, providing timely feedback to students on the assessments, and the managing the logistics of peer-assessment.

References

Ackerman, D., & Gross, B. (2010). Instructor Feedback: How Much Do Students Really Want? *Journal of Marketing Education*, 172.

Afreen, H., & David, G. (2017). All the world's a stage: transforming entrepreneurship education through design thinking. *Education + Training*, *59*(2), 155-170. https://doi.org/10.1108/ET-12-2015-0111

Australian Standard. (1992). *Technical Drawing, AS1100.101 Part 101: General Principles*. Australian Standards online.

Bates, J., Konkin, J., Suddards, C., Dobson, S., & Pratt, D. (2013). Student perceptions of assessment and feedback in longitudinal integrated clerkships. *Medical Education*, *47*(4), 362-374. https://doi.org/10.1111/medu.12087

Engineers Australia. (2013). *Stage 1 Competency Standard for Professional Engineer*. © 2019 Engineers Australia. Retrieved 2 Nov from https://www.engineersaustralia.org.au/resource-centre/resource/stage-1-competency-standard-professional-engineer

Fletcher, A. J., Sharif, A. W. A., & Haw, M. D. (2017). Using the perceptions of chemical engineering students and graduates to develop employability skills. *Education for Chemical Engineers*, *18*, 11-25. https://doi.org/https://doi.org/10.1016/j.ece.2016.07.001

Forman, J., & Damschroder, L. (2007). *Qualitative Content Analysis* (Vol. 11). Emerald Group Publishing Limited.

Fraumann, G., Diriba, H., & Maes, J. (2015). *The role of higher education in 3D printing research and innovation*. https://doi.org/10.13140/RG.2.1.4068.5842

Gamlem, S. M., & Smith, K. (2013). Student perceptions of classroom feedback. *Assessment in Education: Principles, Policy & Practice*, *20*(2), 150-169. https://doi.org/10.1080/0969594X.2012.749212

Grant, M. M. (2011). Learning, Beliefs, and Products: Students' Perspectives with Project-based Learning. *Interdisciplinary Journal of Problem-Based Learning*, *5*, 37-69. https://doi.org/https://doi.org/10.7771/1541-5015.1254

Griffin, P., McGaw, B., & Care, E. (2012). *Assessment and Teaching of 21st Century Skills*. Springer Netherlands. https://doi.org/10.1007/978-94-007-2324-5

Herrington, J. (2006). *Authentic E-Learning in Higher Education: Design Principles for Authentic Learning Environments and Tasks* E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2006, Honolulu, Hawaii, USA. https://www.learntechlib.org/p/24193

Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational Technology Research and Development*, *48*(3), 23-48.

Herrington, J., Parker, J., & Boase-Jelinek, D. (2014). Connected authentic learning : reflection and intentional learning. *The Australian journal of education*, *58*(1), 23-35. https://doi.org/10.1177/0004944113517830

Herrington, J., Reeves, T. C., & Oliver, R. (2014). *Authentic learning environments*. Springer. https://doi.org/10.1007/978-1-4614-3185-5_3

Hung, W. (2015). Problem-Based Learning: Conception, Practice, and Future. In Y. H. Cho, I. S. Caleon, & M. Kapur (Eds.), *Authentic Problem Solving and Learning in the 21st Century: Perspectives from Singapore and Beyond* (pp. 75-92). Springer Singapore. https://doi.org/10.1007/978-981-287-521-1_5

Hursen, C. (2016). The impact of curriculum developed in line with authentic learning on the teacher candidates' success, attitude and self-directed learning skills. *Asia Pacific Education Review*, *17*(1), 73-86. https://doi.org/http://dx.doi.org/10.1007/s12564-015-9409-2

Jacobson, M. J. (2015). Authentic Problem Solving and Learning: Lessons Learned and Moving Forward. In Y. H. Cho, I. S. Caleon, & M. Kapur (Eds.), *Authentic Problem Solving and Learning in the 21st Century: Perspectives from Singapore and Beyond* (pp. 347-354). Springer Singapore. https://doi.org/10.1007/978-981-287-521-1_19

Larson, L. C., & Miller, T. N. (2011). 21st Century Skills: Prepare Students for the Future. *Kappa Delta Pi Record*, *47*(3), 121-123. https://doi.org/10.1080/00228958.2011.10516575

Latham, G., & Ewing, R. (2018). Conversation around questioning and providing feedback. In G. Latham & R. Ewing (Eds.), *Generative Conversations for Creative Learning: Reimagining Literacy Education and Understanding* (pp. 131-140). Springer International Publishing. https://doi.org/10.1007/978-3-319-60519-7_10

Levy, F., & Murnane, R. J. (2012). *The New Division of Labor - How Computers Are Creating the Next Job Market*. New York, Princeton, Oxford: Princeton University Press.

Lombardi, M. (2007). Authentic Learning for the 21st Century: An Overview. Educause Learning Initiative, 1, 1-12.

Molloy, E. K., & Boud, D. (2014). Feedback models for learning, teaching and performance. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology: Fourth Edition* (pp. 413-424). Springer. https://doi.org/10.1007/978-1-4614-3185-5_33

Murphy, V., Fox, J., Freeman, S., & Hughes, N. (2017). "Keeping It Real": A Review of the Benefits, Challenges and Steps Towards Implementing Authentic Assessment. *The All Ireland Journal of Teaching and Learning in Higher Education (AISHE-J)*, *9*.

Nguyen, Q., Rienties, B., Toetenel, L., Ferguson, R., & Whitelock, D. (2017). Examining the designs of computer-based assessment and its impact on student engagement, satisfaction, and pass rates. *Computers in Human Behavior*, *76*, 703.

Pang, T. Y., Kootsookos, A., Steiner, T., Afaghi Khatibi, A., & Crossin, E. (2015). Collaborative design using a digital platform in engineering design course. The Australasian Association for Engineering Education 2015, Geelong, Australia.

Pang, T. Y., Kootsookos, A., Steiner, T., Khatibi, A., & Crossin, E. (2017). Collaborative Project: Exploring the Experiences of Engineering Students' Engagement in Face-to-face and Virtual Peer Learning *Journal of Modern Education Review*, *7*(3), 185-196.

Raymond, J. E., Homer, C. S. E., Smith, R., & Gray, J. E. (2013). Learning through authentic assessment: An evaluation of a new development in the undergraduate midwifery curriculum. *Nurse Education in Practice*, *13*(5), 471-476. https://doi.org/10.1016/j.nepr.2012.10.006

Riley, K. L., & Stern, B. S. (1998). Using Authentic Assessment and Qualitative Methodology to Bridge Theory and Practice. *The Educational Forum*, *62*(2), 178-185. https://doi.org/10.1080/00131729808983805

Roach, K., Tilley, E., & Mitchell, J. (2018). How authentic does authentic learning have to be? *Higher Education Pedagogies*, *3*(1), 495-509. https://doi.org/10.1080/23752696.2018.1462099

Rotsaert, T., Panadero, E., & Schellens, T. (2017). Anonymity as an instructional scaffold in peer assessment: its effects on peer feedback quality and evolution in students' perceptions about peer assessment skills. *European journal of psychology of education*, *33*(1), 75-99. https://doi.org/10.1007/s10212-017-0339-8

Saorín, J. L., Melian-Díaz, D., Bonnet, A., Carbonell Carrera, C., Meier, C., & De La Torre-Cantero, J. (2017). Makerspace teaching-learning environment to enhance creative competence in engineering students. *Thinking Skills and Creativity*, *23*, 188-198. https://doi.org/https://doi.org/10.1016/j.tsc.2017.01.004

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1), 9–20. https://doi.org/https://doi.org/10.7771/1541-5015.1002

Shute, V. J., & Kim, Y. J. (2014). Formative and stealth assessment. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology: Fourth Edition* (pp. 311-321). Springer. https://doi.org/10.1007/978-1-4614-3185-5_3

Simpson, J. (2016). Authentic Learning - Does it Improve Pass Rates and Student Satisfaction? *Journal of Perspectives in Applied Academic Practice*, *4*(2), 62-70. https://doi.org/10.14297/jpaap.v4i2.172

Struyven, K., Dochy, F., & Janssens, S. (2005). Students' perceptions about evaluation and assessment in higher education: a review. *Assessment & Evaluation in Higher Education*, *30*(4), 325-341. https://doi.org/10.1080/02602930500099102

Stuart, R., Ronald, H., & Elsa-Sofia, M. (2012). Basic employability skills: a triangular design approach. *Education + Training*, *54*(1), 7-20. https://doi.org/10.1108/00400911211198869

The Economist. (2015). *Driving the skills agenda: Preparing students for the future*. New York, Economist Intelligence Unit.

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, *72*, 577-588. https://doi.org/https://doi.org/10.1016/j.chb.2017.03.010

van Merriënboer, J. J. G., & Brand-Gruwel, S. (2005). The pedagogical use of information and communication technology in education: a Dutch perspective. *Computers in Human Behavior*, *21*(3), 407-415. https://doi.org/10.1016/j.chb.2004.10.004

Villarroel, V., Bloxham, S., Bruna, D., Bruna, C., & Herrera-Seda, C. (2018). Authentic assessment: creating a blueprint for course design. *Assessment & Evaluation in Higher Education*, *43*(5), 840-854. https://doi.org/10.1080/02602938.2017.1412396

Vu, T. T., & Dall'Alba, G. (2014). Authentic Assessment for Student Learning: An ontological conceptualisation. *Educational Philosophy and Theory*, *46*(7), 778-791. https://doi.org/10.1080/00131857.2013.795110

Wang, J., Dyehouse, M., Weber, N., & Strobel, J. (2012). *Conceptualizing Authenticity in Engineering Education: A Systematic Literature Review*. American Society for Engineering Education.

Wibowo, S., Grandhi, S., Chugh, R., & Sawir, E. (2016). A Pilot Study of an Electronic Exam System at an Australian University. *Journal of Educational Technology Systems*, *45*(1), 5-33. https://doi.org/10.1177/0047239516646746

Wiewiora, A., & Kowalkiewicz, A. (2019). The role of authentic assessment in developing authentic leadership identity and competencies. *Assessment & Evaluation in Higher Education*, *44*(3), 415-430. https://doi.org/10.1080/02602938.2018.1516730