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# 3D printed models to enhance engineering student engagement and learning

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ABSTRACT: Engineering students require strong skills in problem-solving, communication, research and presentation. Traditional strategies to teach 3D modelling by conventional orthogonal 2D drawings are not particularly effective to guide students in their development of spatial knowledge. Students benefit from an innovative engagement approach to connecting engineering theories to industry practice through handling and manipulating the all-round spatial views of 3D printed models, a student confidence-building approach. A new student engagement framework for student learning is presented in this article using the students and peers' reactions obtained from various sources, including the on-line evaluations through Central Queensland University's Student Experience Survey (SES). The impact of this framework in student motivation, engagement and curiosity in learning is assessed. The student satisfaction data obtained from a structural mechanics unit were low initially. With the introduction of innovative student engagement initiatives using 3D printed models, the structural mechanics unit's student satisfaction quickly improved. Both qualitative and quantitative student data are used to triangulate student learning and satisfaction. This enhances not only novel teaching innovations and evaluation, but also stimulates the interest of readers outside the context where the work is produced.

Keywords: Engagement strategy, teaching practices, student motivation in learning, student satisfaction

## INTRODUCTION

A proper student engagement framework is the main key for the student learning through innovation in learning and teaching practices aimed at increasing student satisfaction and retention, and reducing student attrition. A good student engagement framework focuses on improving teaching practices and enhancing students' learning [1]. The framework of student engagement incorporating 3D printed models generates student interest and stimulates curiosity to learn in lower level engineering units, such as structural mechanics at Central Queensland University (CQU). The student cohort consists of school leavers, mature age students and students from diverse cultural backgrounds in both distance and multi-campus modes (Rockhampton, Gladstone, Bundaberg, Mackay and Cairns). One recent student's reaction on the structural mechanics unit can support this statement: *The inclusion of the 3D printed models was very clever and helped to illustrate how different components deflect or fail* (student feedback, 2020).

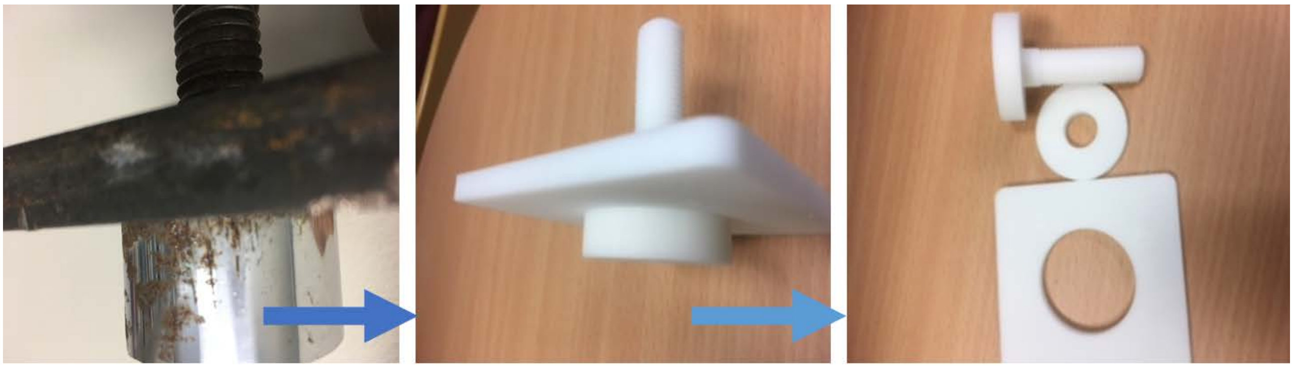
### Development of 3D Printed Model Approach

The 3D printing model development concept began to evolve in 2009, when an actual physical component of an insulated rail joint (Figure 1a) was introduced to a structural mechanics lecture (ENEM12009). The explanation of material of the component and the reasons why it was selected by engineers as the most suitable material for these joints in railway track structures were given. Due to the students' feedback on this physical *model* and their obvious learning, many models (Figure 1b and Figure 1c) were collected. The reflection of student feedback on physical models and how they build student motivation, confidence, engagement and curiosity to grasp complex engineering theories and the evolution of 3D printing influenced the study by Horowitz and Schultz [2]. Therefore, the realisation of the potential to develop many 3D printed models (Figure 2) rather than using physical models was evolved. It was hard to demonstrate the failure analysis without breaking the physical models, and it was in the deconstruction of the 3D printed versions that enhanced student learning occurred.

In 2014, the use of 3D printed models as a student engagement tool to elucidate complex mechanical engineering failure analysis concepts and thinking began. This is impossible with normal physical models because they cannot be broken apart, but 3D printed models vividly demonstrate to students the key concepts. Since then, many 3D printed models were prepared and implemented to demonstrate different failure modes through dismantling objects into parts (Figure 2c). Although many 3D printed models were employed for student learning, it was challenging to engage all students on-campus and on-line to demonstrate how many modes of failure occurred: 360 degrees round views, failure surfaces, types of failure, etc.

a) b) c)

Figure 1: Physical models to engage students to create interest and motivation in learning; a) a rail joint model; b) a support bracket; and c) a turtle model.



a) b) c)

Figure 2: Model of a bracket: a) the physical model; b) 3D printed model of the physical model; and c) shear mode failure of 3D printed model.

## Applications of 3D Printed Models in Teaching

Student engagement and their learning in different disciplines are important. The early applications of 3D printing in teaching to enhance student engagement are in the disciplines of engineering [2-4] and architecture [5][6]. This pedagogy has many advantages, such as enhancing student learning, developing content and problem-solving skills, inspiring creativity and creative thinking [2]. In a recent review article on 3D printing, Ford and Minshall identified six categories of 3D printing usage: to teach students about 3D printing, support technology during teaching, teach educators about 3D printing, produce 3D models that aid student learning, create assistive technology and support outreach activities [7].

As 3D printing models are considered as students' confidence building tools, while they are using them, they acquire knowledge and share it with others instead of using 2D *dry information* out of textbooks [8]. Huang and Lin employed *3D printing-tangible teaching materials* for improving student learning outcomes [9]. In the health educational area, the use of 3D printing models is also very popular for improving both student engagement and learning outcomes in pharmacy [10-12] and anatomy [13][14]. The 3D printing helps create test artefacts in the areas of aeronautics [15], mechanical engineering [16], structural engineering [17][18], biology [19][20], physics [21], chemistry [22][23] and mathematics [24]. However, Ford and Minshall [7] and Ghourchian et al [18] pointed out that the implementation of 3D printing practices remained immature.

## IMPACT OF 3D PRINTING ON STUDENT LEARNING

The use of 3D objects is more professional for student engagement as they can be dismantled to show the students various parts of the models before and after different failure modes due to applied loads acting on them. A significant student benefit of using 3D printed models over the digital version also evolves …*the simple ability to rotate a physical object can often bring new elements into view for evaluation that would not be detectable using digital models alone* [2]. There are a few advantages of using 3D printed models, including …*durability, accuracy, ease of reproduction, avoidance of health and safety issues and cost effectiveness* [25].

The engagement when using 3D printed models with on-campus and on-line students is equally important. Demonstrations of 3D printed models in on-campus classes and on-line modes are effective for student learning of mechanical engineering concepts and thinking. On-campus students can see the demonstration of the breaking down the parts of 3D models under forces and on-line students can see the recorded demonstrations. Both delivery modes have proven to be pedagogically effective. These demonstrations illustrate processes and changes of shape and size of structural members under loads. It enhances the discussions regarding, for example, the difference between rigid body/deformed body motion, thermal expansion of engineering structures, development of tensile and compressive stresses in loaded members and fundamental concepts of forces and force components useful for analysis and design. Even when students on other campuses cannot handle the models, they benefit from them *…all the students from all other campuses have been delighted with this fantastic and effective way of delivery. They are …engaged with [the] barrier-less teaching environment and simplicity of presentations. Students developed problem-solving skills of complex mechanical engineering concepts* (a lecturer in mechanical engineering, Gladstone campus, peer review, 2016). Figure 1c shows a 3D model that explains the concept of the resultant force and the relationship with its components.

In 2014, one on-line student, who is also a high school teacher, pointed out the importance of model demonstrations in developing student mechanical engineering concepts *…I have really enjoyed [the] examples and use of 3D models to demonstrate the concepts. As a high school physics teacher, I have borrowed [the] turtle demonstration to teach my year 11s about resultant and vector resolution and they really enjoyed it and found it easy to understand the concept*. It was exciting to see the 3D model demonstrations stimulated not only CQU students' interest and motivation to learn mechanical engineering thinking, but also assisted in other students' learning outside the university better than what was anticipated. As 3D printing supports the teaching philosophy for students' learning and engagement, CQU invited the author of this article to be a mentor in Scholarship of Learning and Teaching, saying *…[3D printing objectives] have provided leadership to affect systematic change and continual improvement across CQUni* (CQU, 2019). It is exciting to see the impact of the 3D printing learning and teaching strategy at the CQU level. Students also appreciated this approach *[Our teacher] is very good at linking the theoretical side of engineering with simple practical examples. By using a simple steel ruler, he was able to help me understand shear and torsional forces easily and clearly* (student feedback, 2014).

The 3D printed models have a greater leverage over 2D textbook type presentations. The use of 3D models in the classroom at the School of Engineering and Technology (SET) helps to inspire mechanical engineering students in their learning and thinking with a wider view in 3D for failure analysis and design of structural members under axial, bending and torsional loadings, not just imagining the phenomena. Students constantly affirm the benefits of this pedagogy *…the 3D models helped me determine the vital components that are somewhat confusing in 2D dimensions (textbook problems etc) …the problem associated with the 3D printing models was easier to understand as the important points/area, etc, can be shown easily* (unsolicited student e-mail feedback, 2019). Students clearly understand where forces are acting on structures, whether perpendicular to or along a plane, identify the main causes of failure and gain a deeper understanding of key concepts, such as failure surface area for axial loads and their calculations (Figure 2b), how it fails (Figure 2c).

Another student feedback in 2019 illustrates the benefits *…the 3D printed models used to show the stress on the bolts and the possible failure points really helped me showing the effects and failure points possible in real life scenarios. It made the visualisation much easier than just showing pictures during usual lecture slides and dry information of the textbooks* (solicited student e-mail feedback, 2019). The demonstrations of 3D printed model presented here were introduced first in SET, and this work has been recognised by the School. With the SET support and encouragement of this initiative, other teachers now routinely employ 3D model demonstrations in their units *…these 3D models clearly enhanced mechanical engineering student learning even in complex concepts. [These] L&T practices not only influence teaching teams, but also other colleagues…* (a former Dean, SET, CQU, 2018). Each term, nearly 400 students in engineering units learn mechanical engineering through this approach.

The 3D printed models emerged as powerful tools to support students to become independent learners. With the help of the 3D printed models' wider views, students can draw useful diagrams of the loaded bodies accurately and can complete the failure analysis steps independently; students are becoming independent learners. One student's feedback shows an impact of the teaching strategies using 3D printed models *…I found [the] sessions are very useful to learn. …I can apply my skills to other problems to solve them independently. …I genuinely enjoy and learn with the way [it was] taught in this term* (solicited student e-mail feedback, 2019). In 2018, A Professor of CQU commented observing the degree of improvement and sustainability of the teaching performances: *…[the 3D printing] provides ability to significantly improve difficult units deserves recognition and praise*.

The innovative teaching practices incorporating 3D printed models have been the subject of earlier articles by the author [1][26], and this pedagogy recognised as effective. For example, in 2015, the session chair of the Australasian Engineering Education Conference in Geelong, Victoria, summed up that the innovative approach using 3D printed models could be most useful for Australian universities.

The above literature and Fook suggested some important L&T practices that can enhance better student classroom interaction for active learning [27]. These are interactive classroom activities for student engagement and authentic learning. Improvements on student engagement strategies and use of 3D printed models need further studies and developments [7]. The research questions of this study are:

- How effective is the student engagement framework as an environment within which to incorporate 3D printed models as a pedagogical approach?
- Does the assessment of the educational benefits of using 3D printed models to stimulate student learning on technical content and problem solving indicate advantages versus the use of traditional 2D textbook methods?
- What is the extent to which 3D printed models build student curiosity and confidence in learning?

In this article, a new student engagement framework is presented and its suitability assessed, focussing on the set of research questions stated above through qualitative and quantitative student feedback of their learning. This research bridges this gap by considering how the incorporation of 3D printed models into the curriculum may enhance knowledge acquisition and enhance student engagement in the higher education sector. An earlier version of this article was published in the 2018 Australasian Association for Engineering Education Annual Conference [28].

## STUDENT ENGAGEMENT FRAMEWORK

3D printing technology is a growing field in the manufacturing industry and has a transformative approach to industrial production due to the benefits of rapid prototyping to test the efficiency of parts. However, there is a call for more evidence-based research on using 3D printing technology within the education system [7]. This has been identified as a deficit and Ford and Minshall suggest that research needs to be done on where and how 3D printing is being used as a pedagogical approach to teaching and the impact on student learning [7].

Within higher education, keeping students engaged can be challenging, especially when the units are difficult and require hands-on experience [29]. The fields of engineering and architecture have been early adopters of using digital fabrication technology, and research suggests that using a 3D approach to teaching gives students an authentic learning experience by providing hands-on interaction rather than passive learning through reading textbooks and lecture slides. The student L&T model by Huang and Lin also motivated the author of this article to further develop it by enhancing the spatial and dismantling capabilities of the 3D printed models [9].

This research study investigates the effectiveness and viability of the 3D printed model approach (Figure 3) as a teaching tool that can be incorporated into a range of discipline areas at CQU. A full suite of 3D models was trialled in a structural engineering unit (ENEM12009). The introduction of 3D printed models as a student engagement tool to elucidate complex mechanical engineering failure analysis concepts has been shown to promote deeper level thinking. For the mechanical engineering unit (ENEM12009), the 3D printed objects are arranged in twelve small boxes, as per the weekly unit content, in order to employ them in chronological order. Different stages of the student engagement model (Figure 3) are discussed below. This project design follows the 4 stages of the 3D printed model approach:

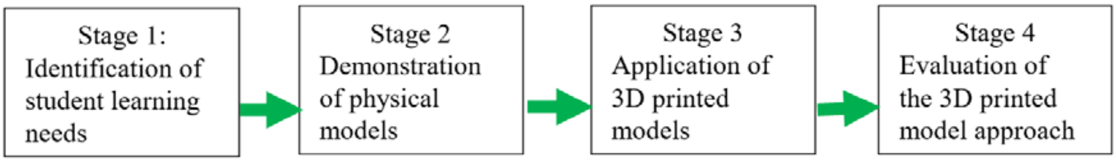



Figure 3: A new student engagement framework for better L&T practices to enhance student learning.

Stage 1: Student needs - the students' learning needs are identified around the types of physical models required to teach the technical content (example Figure 2a). This can be accomplished through reviewing the unit content and identifying key material to be investigated. In addition, identification of gaps in students' knowledge are established through anecdotal notations from lectures, tutorial sessions and workplace discussions.

Stage 2: Physical models - introduction of physical models helps students to visually see the content being taught. Because physical models elucidate student learning, the collection of physical models relating to weekly content of lectures and tutorials is carried out. However, it is sometimes hard to show how these physical models can fail under different loadings. Students are unable to see 3D spatial views of the failed surface of the physical models, which reduces their depth of understanding around the content. Figure 2a shows an example of a physical model used in a mechanical engineering lesson.

Stage 3: Application of 3D printed models - using 3D printing technology, 3D printed models requiring specialist design are fabricated to imitate the physical models. Research technicians, alongside the support of the lecturer, take a physical model and replicate it in 3D form. Figure 2b shows a 3D printed model of a physical model. Figure 2c is its dismantled parts to show spatial views of the failed circular surface of its shear failure mode. Students can visualise how damage can be sustained in such a replica of a 3D model.

Stage 4: Evaluation of the 3D printed model approach - the final stage of this process is an evaluation of the 3D teaching tool. This evaluation investigates the development stage and the process of replication of the physical models alongside the educational approach in implementing it into the class lesson. This final phase seeks feedback from the students involved in the classes to establish the benefits to their understanding of the concepts being taught.

Qualitative analysis methods are the main analysis tool for the collected data completing the CQU ethical clearance steps. Thematic analysis is used to categorise the data as it emphasises pinpointing, examining and recording patterns/themes within the data set. The thematic analysis provides a rich and detailed, yet very complex, account of the data. Some results can be displayed in the form of graphs, charts, tables and other formats that allow for better interpretation. The MS Excel capabilities are used to analyse data.

RESULTS AND DISCUSSIONS

The impact of the framework of student engagement through 3D printed models (Figure 3) for student learning is discussed and presented considering both qualitative and quantitative student and peer data obtained from the SES and other reliable sources. The classroom and non-classroom activities focus on students' engagement and collaboration, such as proactive two-way communication in lectures and tutorials, reflection questions, quizzes and the like. Students' unsolicited feedback thorough SES confirms that this engagement framework works well to evolve a very good student learning journey. Each week, a few 3D printed models are employed in the lecture, tutorial and workshop sessions to demonstrate the content in a richer and more engaging manner than the usual textbook-based style. The students can learn a complex concept of determining the correct area for failure surfaces easily by not having to imagine or articulate a 3D view of it. This approach excites students and has inspired many peers to successfully adopt similar practices in their teaching.

The teaching approaches employing 3D printed models positively motivate and inspire the students to learn and influence the overall student experience and students' future employability, especially when dealing with the diversity of students from different cultural backgrounds. It worked well because of the collaboration with colleagues, teaching teams and local industry for which expertise was provided in mechanical engineering (2008-2017) on the engineering reference committee, to incorporate industry requirements into CQU engineering courses. Therefore, incorporated innovative industry-focussed activities were developed that enhanced mechanical engineering learning, thinking and practices including independent design and analysis, problem solving, project and team management and presentation skills. Students learn to think like mechanical engineers through the 3D printed models and demonstration activities. These allow the students to improve the technical and professional skills that prepare them for employment in the mechanical engineering field and ensure that they are industry work ready graduates.

The School (SET) requests the employers of CQU engineering graduates to rate them by comparing the student's competency as a newly graduated engineer against the Competency Standards of Engineers Australia on categories, such as knowledge base, engineering ability and professional attributes with a 5-point Likert scale. CQU engineering graduates were rated very highly (Figure 4) by employers at 4.14 in 2015, 4.15 in 2016, 4.17 in 2017 and 3.94 in 2018, well above the average rating of 3. It clearly articulates the connection between the students' development of problem-solving skills using 3D printed models to the knowledge and engineering ability skills required in workplaces.

Observational evidence from industry illustrates the capability and workplace impact the students are having …*[the] ex-students [with 3D printing experience are] performing comprehensive professional set tasks to a superior standard. Their technical skills and underpinning knowledge gained from previous learning ensure that they complete both routine and non-routine railway engineering tasks with confidence. Those ex-students are the model engineering graduates for Aurizon and other railway engineering companies. These students have had a very positive impact on the business we are in and are a tremendous asset attributed to the teaching philosophy including 3D printed models* (a principal Asset Engineer, Aurizon, solicited email, 2019). It is also supported by literature of Ford and Minshall [7].

The impact of the influential 3D printed model L&T student engagement practices is also supported by the QILT national higher education survey data [30] (funded by the Australian Government Department of Education, Skills and Employment) relating to CQU undergraduate engineering on current student experience, recent graduate satisfaction and recent graduate employment and salary. These data put into context how the innovative L&T practices employing 3D printed models are linked to the engineering student experience at CQU (Table 1). It shows that, in all areas of student skills development, teaching practices, engagement with students and resources and facilities, the CQU undergraduate engineering students are rating those positively over national averages. In relation to recent CQU engineering graduates, 85.8% of them were satisfied with how their skills improved compared to the national average (NA) of 83.3%, and 89.1% of them found full-time employment compared to the NA of 82.4% with a median graduate salary of $70,400 (NA of $65,000) [30].

Through the SES in CQU's Moodle site of the structural mechanics unit, the unsolicited quantitative data of student satisfaction and feedback rates are obtained. The student's satisfaction is rated on a 5.0 Likert scale and 4.0 out of 5.0 is the corporate target. The student satisfaction rate of 4.0 or over in a unit would be considered as a green flag unit and below 3.0 as a red flag unit that should be improved. Student feedback rate of 50% is considered as the corporate target. Table 2 provides student satisfaction and feedback rate data from 2010. It shows a very good L&T performance in the recent years. Before 2011, the data set was poor and below the corporate targets. It started improving from 2011 due to the employment of physical models. Initially it was challenging to use 3D printed models effectively and the student satisfaction rate was variable. Lately, through the effective engagement of the models, the student satisfaction and feedback reaction are more positive. The satisfaction scores are increasing with 4.3/5.0 in 2020 (Table 2).

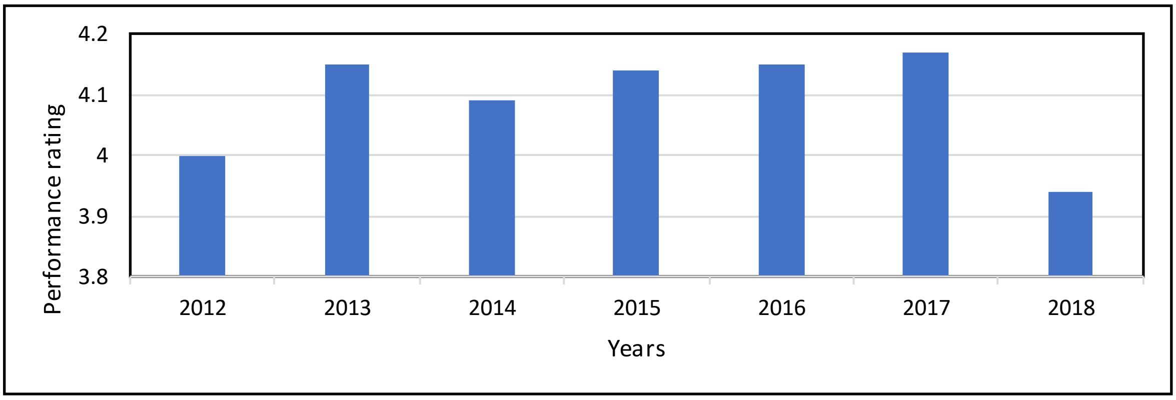



Figure 4: Employers' evaluation of CQU engineering graduates.

Table 1: CQU undergraduate engineering student survey data, 2017-2019 [30].

| Key data | Has a positive overall experience (national average) | Were positive about their skills development (national average) | Rated teaching practice positively (national average) | Were positive about their interactions with staff and students (national average) | Were happy with facilities and resources (national average) |
|---|---|---|---|---|---|
| Current student experience | 73.1% (74.4%) | 83.5% (79.4%) | 77.8% (75.9%) | 71.3% (68.0%) | 84.9% (82.7%) |

Table 2: Satisfaction and response rates for Structural Mechanics.

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Student numbers | 34 | 30 | 37 | 20 | 28 | 46 | 21 | 57 | 42 | 41 | 29 |
| Student satisfaction | 2.0 | 4.0 | 4.0 | 4.1 | 4.1 | 3.6 | 4.4 | 3.8 | 4.0 | 4.0 | 4.3 |
| Student feedback rate (%) | 26 | 25 | 65 | 67 | 57 | 67 | 70 | 60 | 55 | 60 | 54 |

Observing initial inadequate students' L&T performance, a formulation of some novel *4-point* L&T [1] practices was carried out, where engagement and communication was at the core of those practices. For achieving sustained teaching performance that ensures student learning, the incorporation of 3D printed models, toys, tag questions, animations in lectures, etc, were employed. By introducing engagement approaches and L&T practices and making the lectures/tutorials interactive, very good student satisfaction and response rates (Table 2) were achieved. That progress influenced further updating the teaching philosophy by incorporating additional elements into the enhanced *4-point* strategy and engagement agenda, such as the use of simulation software, more 3D printed models, guest lecturing and industry site visits with a view to achieving a 4.5 or more out of 5.0 student satisfaction score.

The interactive engagement can be further illustrated using more students' solicited data from SES on some Moodle site descriptors. They are Moodle site navigation, assessment task, assessment return, assessment feedback, assessment requirement, learning resources and overall satisfaction. Figure 5 illustrates these data in the recent years and it shows that they are performing well due to the inventive engagement and collaborative activities.

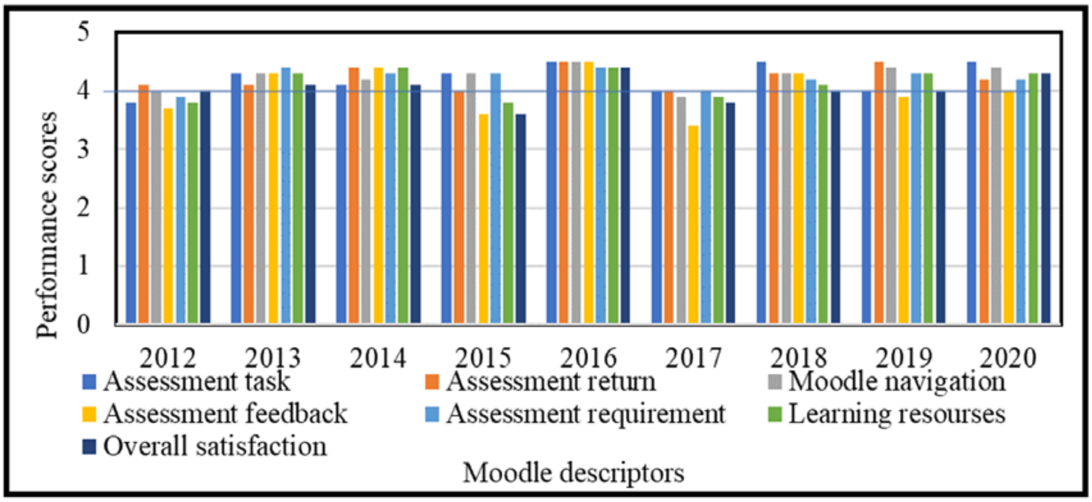



Figure 5: Student rating on various descriptors on a 5.0 Likert scale.

All these descriptors are directly or indirectly related to student engagement. The assessment tasks are relating to providing engineering problems in context with good objectives and scopes. The assessment returns lead to both useful qualitative and quantitative feedback provided back to students in the two weeks after the date of submission. Good student engagement through Moodle site navigation means the site must be user friendly with similar resources available in a single place.

The assessment feedback is the most important student engagement, and it yields both qualitative and quantitative feedback to students for improving good points and rectifying any issues. The assessment requirement, on the other hand, means that requirements relating to scopes, analysis, verification, submission details, etc, are explained clearly. The learning resources incorporating 3D printed models relate to the quality of assignments that support student learning. The overall student satisfaction results combine all the effects from all the foregoing descriptors (Figure 5).

All the descriptors are generally over the CQU corporate targets with the exception of assessment feedback and student satisfaction. Of them, except assignment feedback, other descriptors, such as Moodle navigation, assessment tasks, etc, are being maintained at a level over the corporate target of 4.0/5.0. The students want to engage with the coordinators to improve further and further in their problem-solving skills by getting useful directions given in the assignment feedback. Detailed feedback is the key to achieving a level over the corporate target. As it is indicated, there are many elements in student engagement, including the software used and its availability, especially for distance students. If there are problems in accessing software from their home computer, they are not happy and satisfaction results fall. Because of this issue, student satisfaction scores were below the corporate target in 2015 and 2017 (Figure 5).

Rather than student satisfaction data over the years, student learning can be linked to their performance relating grades. Figure 6 shows these details of the structural mechanics unit, a fundamental lower level unit. Student performance grades of HD (high distinction), D (distinction) and F (fail) indicate that most of the students are achieving Ds, resulting in a bell-shaped curve (not shown) for all grades including C (credit) and P (pass). The failure rate is quite low, below 20%, which is lower than the CQU average. The HD rating on the other hand is being maintained at a good level. The HD and D data suggest the students are learning the unit very well.

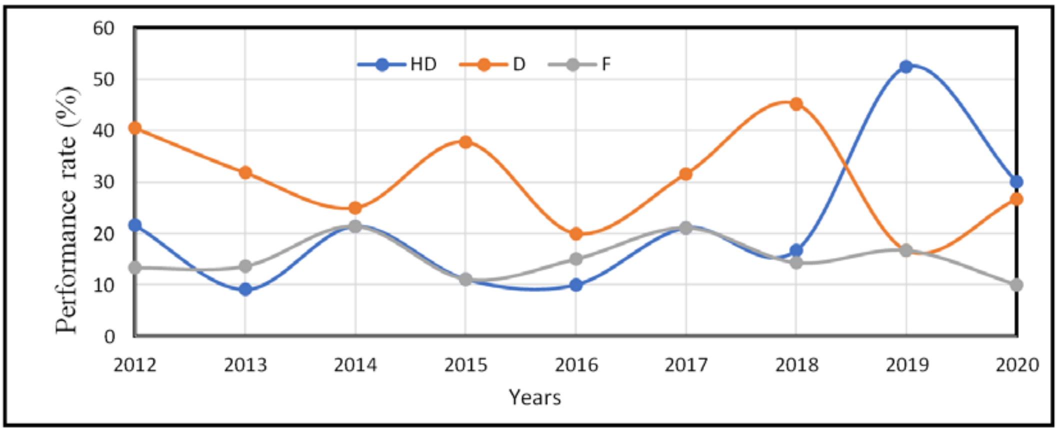



Figure 6: Performance rating (%) of student learning.

It is interesting to note that, for a lower level unit like structural mechanics, the student performance data for on-campus and off-campus (distance) students is different. It is evident from Hall et al that on-campus students' performance is better in total marks and their failure rate is significantly lower [10]. The author of this article agrees with the conclusion made by Hall et al that both on-campus and off-campus students are performing better in assignments and worse in examinations [14]. However, the satisfaction of both categories of students can be improved by proper on-campus and off-campus engagement strategies as discussed in this article.

As the effectiveness of proper student engagement positively influences student interest and learning, the new student engagement model incorporating 3D printed models is evaluated though a yearly SES process considering student satisfaction and feedback. A few recommendations are proposed through an annual unit enhancement report (AUER) to the programme committee of the School with a view to implementing improvements in the next offerings. The student satisfaction and performance of the current year was benchmarked against that of the corporate target.

The novelty and significance of this contribution relies on effective student engagement through innovative teaching practices that suit student study time. If students like such teaching approaches, they involve in engagement and contribute to learning conversations; thereby their satisfaction and learning evolve. Smith et al iterated that *…the use of 3D printed models was found to support learning; average test scores for those in the 3D printed model group were 14.4% higher* [31]. Moeck et al stated that *…the 3D printed crystallographic models offered a significant benefit as the average test score of 3D printed group was 47% higher than a control group that did not use them* [32]. Some statistical analyses showed that *…pre-test and post-test scores for the group using 3D printed models were significantly higher than the other groups* [7]. This supports an important proposition that the 3D printed models offer *…a novel, accurate and effective substitute* [25].

Through the qualitative and quantitative student feedback regarding the use of 3D printed models, it was ensured that student learning was evolving. It was also observed from student qualitative data that the student satisfaction was gradually increasing through the creation of a better student engagement and learning environment. As a result, it has not only evolved a lot of interest to CQU teachers, but also to educators, teachers and readers outside of CQU.

CONCLUSIONS

The innovative engagement using 3D printed models in place of physical ones has improved the student performance and understanding of unit contents. The teaching strategies enhance mechanical engineering students' grasp of putting complex engineering theory into practice. The students are more engaged in their approaches to mechanical engineering concepts as a result of watching and manipulating 3D printed models, an inventive approach that has been developed and shared across the School. It has now become an influential student learning tool and has been successfully implemented by other universities beyond CQU. Through the innovative approach to 3D printed models and demonstrations, students are transformed into engaged, curious and confident mechanical engineers. From 2011 and onwards, the students' satisfaction data in the various Moodle descriptors are very good and the following conclusions can be made:

1. Proactive student engagement activity creates enhanced student learning and satisfaction.
2. It helps to increase student feedback rates.
3. It inspires the students to learn.
4. It also inspires other colleagues to employ it.
5. It positively supports the university's engagement agenda.
6. It can be of great interest to readers and teachers outside of CQU.

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