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Portfolio Based Assessment in Mechanical Engineering Design

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ABSTRACT

CONTEXT

Whenever engineers make objects, design drawings are the central descriptive media enabling that work. Technical sketching is an effective way to present and visualise a planned object without the need for words. In the field of engineering, design drawings are the singular skill that unifies all design and manufacturing processes. Its importance to engineers cannot be overstated. Even in today's networked world, technical sketching is still critically important, although formal Technical Drawings (TD) have largely been superseded by Computer Aided Design (CAD). Understanding the creative scope of technical sketching alongside proficiency in using CAD tools to generate production-ready drawings takes students time, patience, and self-reflection.

PURPOSE

This practice paper outlines an integrated portfolio-based assessment approach which scaffolds student learning through the distribution of content via weekly tasks aiming to increase student engagement and student learning. Such a method allows students to gain more of a fundamental understanding of the underlying principles being studied.

APPROACH

Two portfolio documents were created for the Introduction to Mechanical Engineering Design course (MECH1110) at the University of Newcastle in Australia. These included a Technical Sketching Portfolio (TSP) and a CAD Portfolio, each containing weekly tasks. Each portfolio covers the full 12-week semester, at 30% each, and have continual themes that leverage off each other. Since the development of the portfolio-based assessment approach in 2020, student feedback (quantitative/qualitative) and grade data has been collected to identify the impact of the approach.

OUTCOMES

The effectiveness of a portfolio-based assessment is evident through evaluation data. Grade performance has resulted in a shift to higher average grades without content or assessment becoming any 'easier'. This is attributed to students more effectively consolidating their learning over the semester and making more effort to 'shine' with the portfolio tasks. With restructured assessment, the course also returned and sustained consistently high Course Experience Survey (CES) results (average of 4.7/5.0 since the implemented changes in 2020).

CONCLUSIONS

This paper has presented a portfolio-based assessment approach which has shown to have immense potential for any skill-based course. In the MECH1110 implementation, student satisfaction and increases in average grades was shown. This is attributed to weekly feedback and support in tutorial sessions, which resulted in greater student engagement and motivation in their studies.

KEYWORDS

Portfolio, Assessment

Introduction and Background

Technical sketching is an effective way to present and visualise a planned object without the need for words and is thus the singular skill that unifies majority of design and manufacturing processes. Its importance to engineers cannot be overstated. Even in today's networked world, technical sketching is still critically important, although formal Technical Drawings (TD) have largely been superseded by Computer Aided Design (CAD) models. Sketching skills are taught and developed in the Introduction to Mechanical Engineering Design course (MECH1110), which has an average annual enrolment of 270 students, at the University of Newcastle in Australia. Understanding the creative scope of technical sketching alongside developing proficiency in using CAD tools to generate production-ready drawings takes time, patience, and self-reflection. Acquisition of these skills makes MECH1110 pivotal in developing engineering design knowledge and skills that will last a graduate's career lifetime.

As with any skill, proficiency comes with continual and repetitive practice. The previous structure of the course included the first major sketching assessment being submitted in Week 6, followed by a major CAD modelling assessment being Submitted in Week 10. Following this, students were assessed with a CAD modelling quiz in Week 12 and a formal sketching examination held during the exam period in Week 14/15 resulting in an 'end-heavy' assessment load. From discussions with our students and the work they submitted, we could see the skills allegedly being developed in earlier assessment tasks within MECH1110 weren't being retained and used in the final assessment. It was also observed that most students would be 'cramming' the assessment items into a few days prior to the submission time leading to a lack of retention of the skills which are to be developed during the respective assessment items. We knew there were pedagogical challenges around trying to assess students early in the semester while the required skills are still being developed. One of the key aspects which led to the investigation of alternative assessment methods for skill-based courses was to ensure students were motivated with the content:

> *"the role of assessment is so great – in students' motivation, study time, graduate outcomes, and curriculum design – that it must be [made] engaging, relevant, authentic and intrinsically interesting"* (Nicholson, 2021).

Reflecting on our teaching philosophy, and on what we knew about our student cohorts as well as exploring the assessment literature, led to the implementation of a portfolio-based assessment approach. Employing such a scaffolded portfolio-based assessment approach also aims to enable students to be more organised, which can lead to an increase in student motivation and lower levels of study-related exhaustion and stress. Motivating and inspiring students to learn is challenging but is one of the most rewarding aspects of teaching. The regional Australian University where this study was undertaken has a student cohort which is diverse where 2019-22 averages show 44% are first in family to university, 31% come from low socioeconomic circumstances and/or remote locations, and 16% are international. These are all contexts that may negatively impact student success, so we needed to broaden opportunities for inclusion and equity. For most of our students, MECH1110 is one of four introductory courses in their first semester of study, at the start of their university careers. Transition pedagogy research suggests first year students can feel overwhelmed, hence lacking confidence and engaging poorly with course content:

> *"problems in self-regulation of learning … planning, monitoring and reflecting on one's own learning, are related to students' experiences of exhaustion at the beginning of their university studies"* (Räisänen et al., 2021, p.1136).

The assessment strategy employed needed to effect significant positive change, facilitating students to reflect frequently on incremental achievements that would motivate them to develop their industry-critical skills in TD/CAD. Convinced by the description of portfolios as:

> *"learner-centred, promote reflective practice, and help students better understand and achieve complex learning outcomes"* (Taylor et al., 2017, p.1),

we decided on a portfolio-based assessment, functionally strengthened by weekly feedback that feeds forward into the next task (Quinton & Smallbone, 2010). However, we knew this approach would have its challenges.

> *"Students find portfolios very time-consuming, causing them a great deal of anxiety"* (McMullan, 2006, p.334)
>
> *".. the process can actually negatively impact on other aspects of their learning"* (Flores et al., 2015, p.1524)

Pedagogically, we were satisfied with the significant evidence that portfolio assessment would provide the structure needed *"to assess complex professional skills*" (Taylor et al., 2017, p.1), especially if built authentically by using examples of real-world components from our research (rather than textbooks).

By way of background, the use of portfolio-based assessment approaches has been implemented in various engineering courses throughout the years. One of the first documented implementations for the use of portfolios in an engineering course was documented in the work of Payne et al. in 1993. In this research, rather than merely using portfolios as a method of alternate assessment, it was determined that the use of portfolios,

> *"…makes the process more open to view, and because of its novelty, staff are having to be very clear about what needs to be assessed, and what it is appropriate for a portfolio to cover."* (Payne et al., 1993, p.41).

This can lead to a more transparent form of learning where students can both forward plan and reflect on prior learning. Alternative forms of scaffolded learning, such as weekly quizzes, can have their benefits but when considered in the context of a skills-based course, skill retention can become an issue. This is attributed to students 'cramming' for a quiz and once the quiz is complete, it can be common practice that students do not revisit or reflect on prior learning. When portfolios are considered however, as students will continually work from the same portfolio (document) for a course it becomes common practice for students to revisit and reflect on prior learning as the document will be continually used. Portfolio based assessment also has the benefit of being a,

> *"… much more rigorous means of assessing the potential professional than the use of examination by themselves."* (Payne et al. in 1993, p.38).

In this practice paper we identify the outcomes from implementing a portfolio-based assessment approach incorporating weekly feedback for students. We thematically analyse student feedback as captured in a survey of undergraduate engineering students within MECH1110 at the University of Newcastle in Australia.

Method

With the decision to implement a portfolio-based assessment scheme for MECH1110 in 2020, initial development began when COVID-19 struck. Compelled by the various restrictions during 2020, whilst introducing a new portfolio assessment approach we had to re-design the course for blended delivery, allowing our students to study either remotely (online) or on campus. Though so many changes at once was not ideal, we were satisfied that the content and high-quality learning resources produced engaged students in both online and face-to-face environments. Students also appreciated this approach:

> *"I loved the opportunity to study solely online, it was extremely helpful during difficult personal times and was also very helpful to balance around my employment and other subjects."* (CES feedback, 2020).
>
> *"The content and labs were extremely engaging … very useful towards my degree"* (unsolicited student feedback, 2021).

We overcame the initial challenges of portfolios and blended delivery by giving students extra support along with effective empathetic guidance about portfolio requirements. By way of

example, Figure 1 shows a weekly ‘module’ from the Technical Sketching Portfolio for MECH1110. Each portfolio task requires students to work through a ‘module’ containing the set of tasks to be drawn/modelled as well as reflective questions relating to the content being studied which is taken from the formal lectures. Each portfolio module is leveraged from the previous weeks work where the difficulty is increased throughout the semester. Due to the progression of learning, students should not jump forward in the documents/miss modules, so they fully gain an understanding of the principles being studied.

In the Technical Sketching Portfolio, students start in Week 1 by drawing basic shapes to get a feel for the level of detail required in free hand technical sketching (beginning to develop muscle memory). From here concepts such as third angle projection, isometric views, section views, etc. are introduced weekly to allow students to build a solid skill set to further build their muscle memory. The final portions of this portfolio introduces dimensioned detailed drawing concepts as well as tolerances which are essential for manufacturing.

For the Computer Aided Design (CREO) Portfolio, students start in Week 1 by modelling basic shapes (such as a cube) to get a feel for how the software package works (beginning to identify the operations required to perform various modelling techniques). From here concepts such as pattern and constraint driven modelling, assemblies/exploded views, modelling at the assembly level, mechanism analysis, etc. are introduced weekly to allow students to build a solid skill set. Similar to the Technical Sketching Portfolio, the final portions of the Computer Aided Design (CREO) Portfolio introduces dimensioned detailed drawing concepts as well as linear and geometric tolerances which are essential for manufacturing.

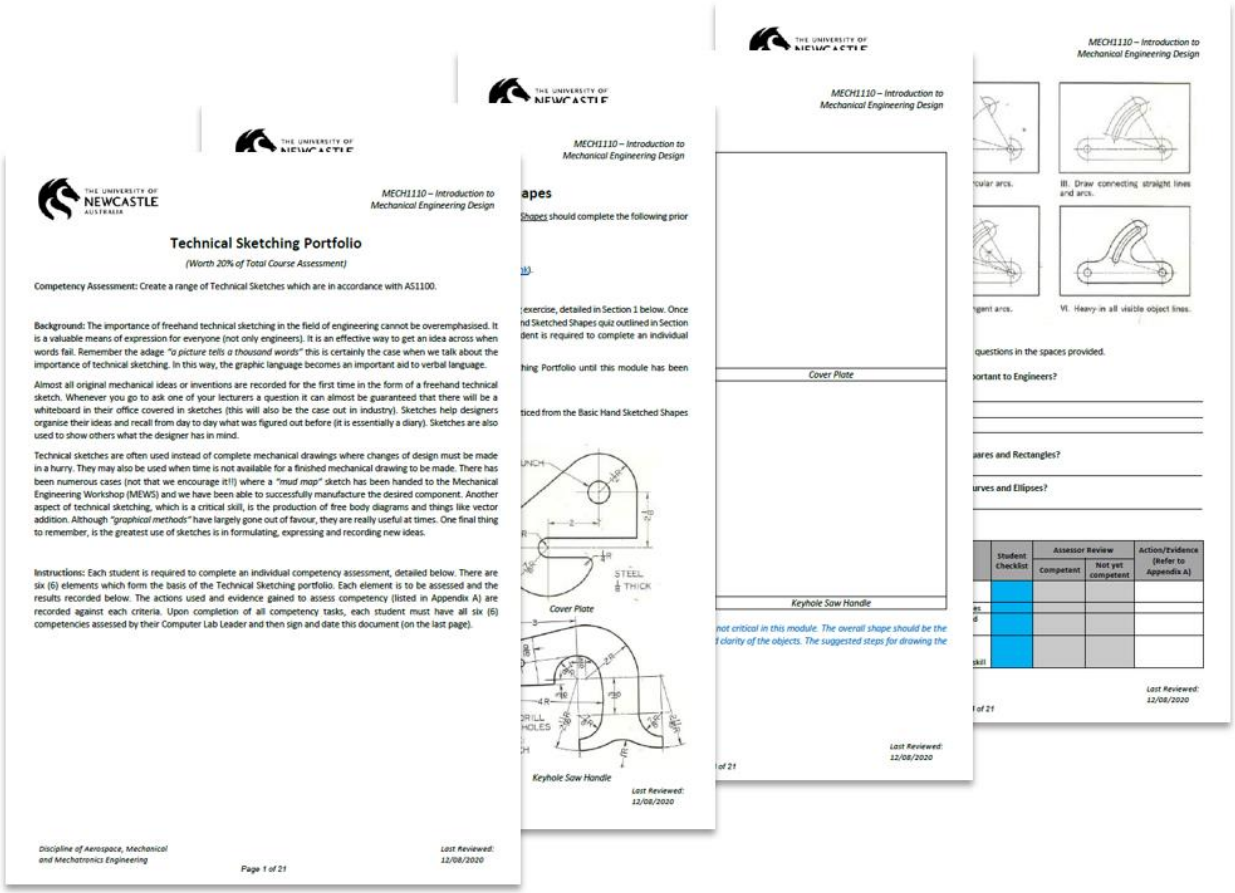

Figure 1: Technical sketching portfolio weekly module.

This assessment scheme has allowed students to receive constant feedback where multiple submissions allow each student to continually develop their skill set and receive the feedback and encouragement if they need to work further on a particular skill. These portfolios consist of weekly tasks ('modules') where students continually build an industry critical skill set. Additionally, the portfolio scheme has also allowed for a more structured assessment schedule to be employed. To ensure students are well informed of the requirements of the portfolio assessment items, videos are recorded giving an overview of the requirements. Our students found these videos to be extremely helpful where all the comments received to date are very positive where most students had a much clearer idea of the assessment requirements after reviewing the videos.

We also responded to student feedback from the initial implementation of the portfolio-based assessment scheme in 2020/2021. For example, originally the TD/CAD portfolios covered 6/12 weeks and were worth 20%/40% respectively. Each portfolio now covers the full 12-week semester, at 30% each, and have continual themes that leverage off each other. This adjustment improved students' engagement with both aspects of the course, and retained elements of the TD work that could be glossed over in the portfolio's initial 2020 format. Using a scaffolded portfolio assessment also enabled students to be more organised, which led to lower levels of study-related exhaustion and stress and motivated learning:

> *"… workload was spread out in a very manageable way which made this course and my other courses much more enjoyable and a lot less stressful"* (CES feedback, 2022).

The weekly portfolio submissions more fairly distribute not only students' assessment load, but also the marking/feedback load for academics and tutors. This allows us to dedicate more time to support all our students with the best possible learning and university experience. This approach facilitated our focus on assisting all students, regardless of background or learning style, to participate and achieve success. We simply ensured no-one was left behind.

The structured feedback regime and weekly tutorial sessions, together with multiple submissions, allowed each student to continually develop their skill set and receive continuous feedback and encouragement as they worked towards their goal. The feedback was distributed using the process flow chart shown in Figure 2. Throughout the semester, students were able to submit their work for review during a weekly livestream Q&A session (typically 10 to 15 students engaged in this initial submission process) which was held prior to all tutorial sessions. Although only a small student subset engaged in the initial submission process, the engagement during the livestream sessions was exceptional where most students were able to consolidate their learning during these sessions. Based off this initial feedback, students would be encouraged to update their own submissions prior to their tutorial session. Once students entered their tutorial session, rapid feedback on their portfolio module was supplied and areas for improvement then identified. Students would then have the remainder of the tutorial session to fix any of the areas identified for improvement further consolidating their learning. This process allowed all marking to be completed during the tutorial sessions and allowed for students to obtain immediate feedback. The combination of the portfolio-based assessment approach and the weekly feedback process (outlined on Figure 2) that has been implemented in MECH1110 has increased success as shown with a dramatic increase in grade performance (shown in Figure 4).

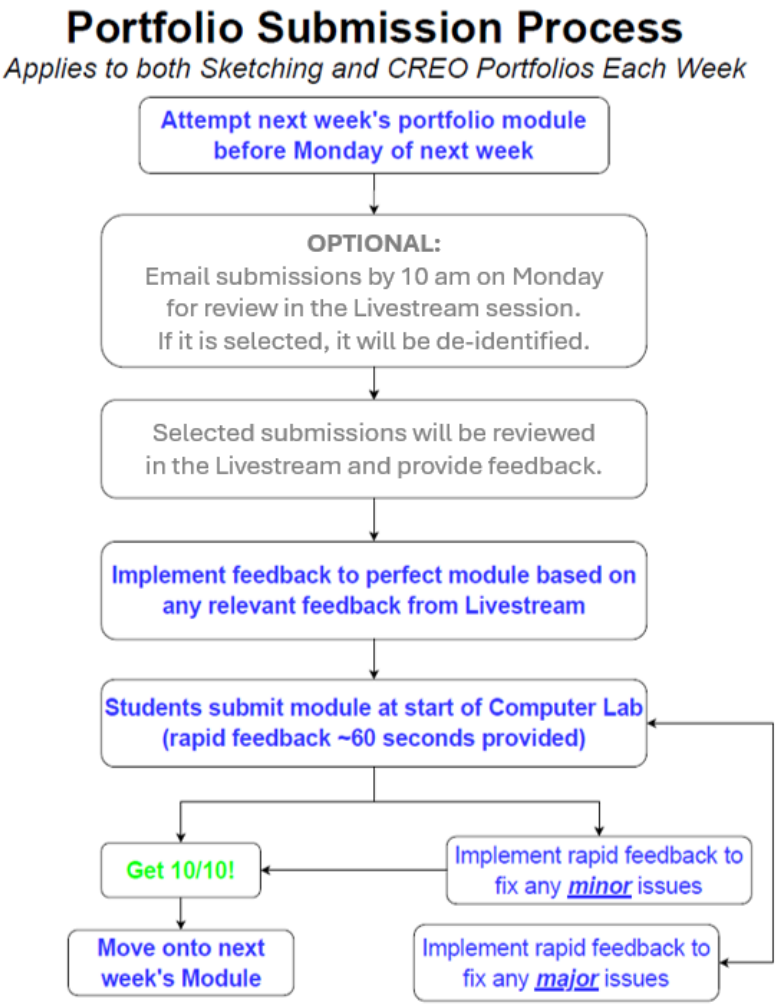

Figure 2: Portfolio submission process.

The submission process, shown in Figure 2, allows us to foster student development, stimulate curiosity and help students to develop independence in their learning. Giving feedback at the start of tutorial sessions gave students time to reflect and decide how to address areas identified for improvement.

> *"The way the course was structured with the portfolio allowed working through at a steady pace and provided constant feedback on progression was fantastic"* (CES feedback, 2021).
>
> *"Having the weekly submission aspect of the course allowed students to receive constant feedback for their work, further guiding them to a deeper understanding of the technical content"* (CES feedback, 2022).

By employing a scaffolded assessment approach, it was observed that most students presented increased skills, shown with advanced CAD functions and conceptual design concepts. This resulted in significantly stronger outcomes than those years prior to the implementation of the portfolio-based assessment approach. By way of example, in the later parts of MECH1110, students are required to conceptually design components for a task which has few restrictions (open ended problem). This subjects the students to a much deeper level of critical thinking which ultimately increases skill retention. This can be attributed to students needing to determine the way components will be manufactured and interact with other components (assembly level modelling). Not only does this consolidate some of the prior learning from previous portfolio modules, but it also ensures that students take more ownership for this portion of their learning as it is something they have developed from "scratch". It is important to note that there is a need to explore the longer-term effects of this assessment strategy on students' learning in later years. The authors are currently working on further research to identify the influence of the portfolio

assessment approach in relation to retention of skills in the later courses on Mechanical Engineering Design at the University of Newcastle.

The ‘assessment roadmap’ was another innovation developed to support the portfolio assessment scheme in MECH1110. This infographic (shown in Figure 3) gives a visual representation of all the major assessment due dates alongside an overview of the content being studied throughout the semester, complementing the portfolio assessment approach. Students can review their position on the map at any time during the semester and ensure they are always aware of the content they should be working on in a specific week and any upcoming assessment milestones.

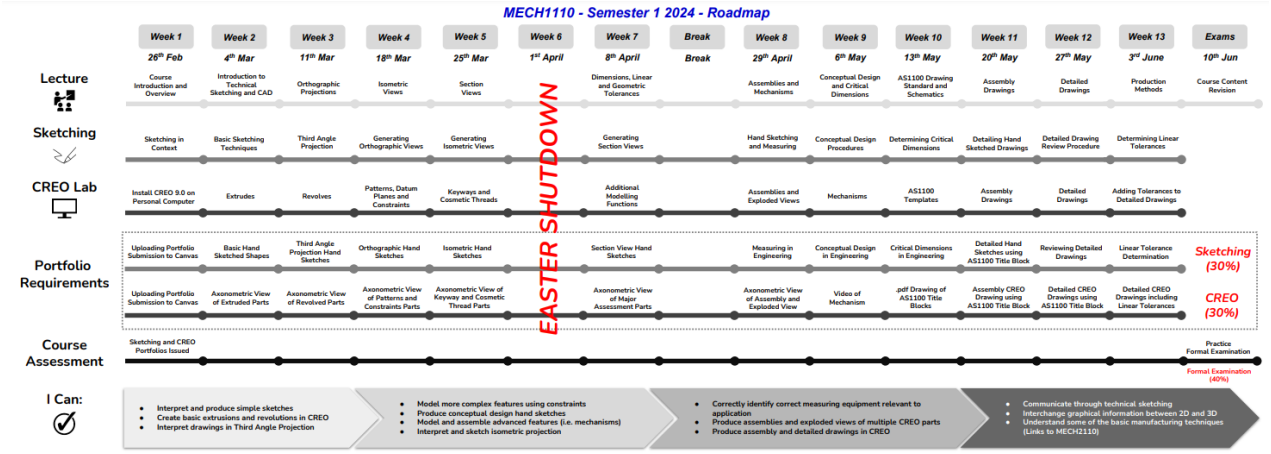

Figure 3: MECH1110 course roadmap.

The roadmap has been invaluable for stimulating students’ curiosity and learning independence. By using the roadmap with the portfolio assessment, students can plan to work ahead if they choose to, making their workload from other subjects more manageable. By facilitating this more autonomous approach to workload planning, students with diverse non-study responsibilities appear more likely to continue studying:

> *“I liked that each week was organised and the roadmap helped me see exactly where the course was going. I’d love to see every course have their own roadmap just like this …”* (CES feedback, 2020).

Outcomes

The effectiveness of the redesign and portfolio assessment within MECH1110 is evident through evaluation data. By integrating assessment that scaffold student learning through the distribution of content via weekly tasks, students have gained more of a fundamental understanding of the underlying principles. By providing weekly feedback and support in tutorial sessions, we have found students are more engaged with coursework and motivated in their studies. Their success in MECH1110 boosts confidence, enabling good outcomes in other Semester 1 subjects, ensuring these ‘first-years’ successfully adjust to university life and have the best possible first-year experience. Additionally, we have found that MECH1110 also assists in the ‘on-boarding’ experience of the students (i.e. MECH1110 is a stabilising segue into university life/other courses).

Since implementation of a portfolio-based assessment regime, grade performance (shown in Figure 4) shows a shift to higher average grades. This has been achieved without content or assessment becoming any ‘easier’. For example, since implementation has occurred, more advanced CAD principles such as mechanism analysis has been added to the curriculum. This structured approach allows students to more effectively consolidate their learning over the semester and made more effort to ‘shine’ with the portfolio tasks. With restructured assessment, the course also returned and has sustained consistently high CES results (as shown in Figure 5). It is important to note that due to the variety of changes implemented simultaneously, the

increase in sustained consistently high CES results is most likely a combination of the portfolio-based assessment and good online resources. Future work in additional courses will focus more solely on the implementation of the portfolio-based assessment approach whilst keeping the online resources the same to obtain a more thorough investigation.

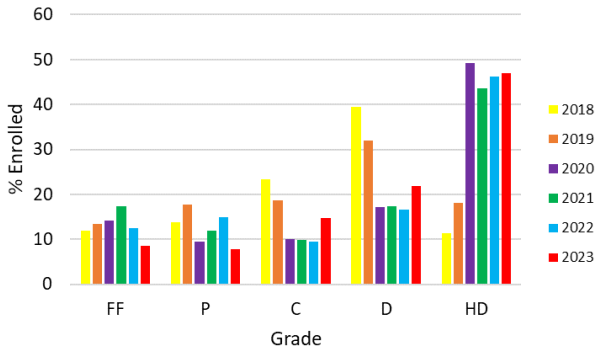

Figure 4: MECH1110 course grade distribution (Course Assessment Return, 2018-2023).

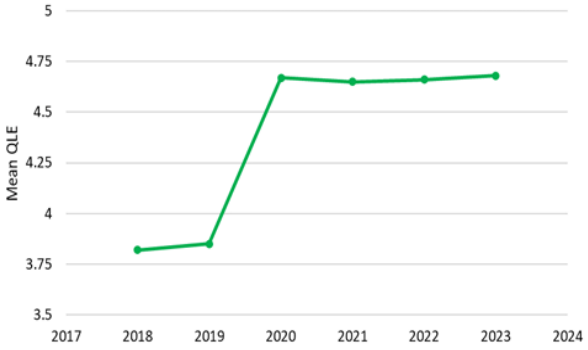

Figure 5: Mean Quality Learning Experience (QLE) rating (CES Surveys, 2018-2023).

By way of background, the previously identified issues of an 'end-heavy' assessment load for MECH1110 led students to study related exhaustion and anxiety as they would need to 'cram' for the final CAD modelling quiz and the formal sketching examination (in addition to exams for other courses they were studying). This was attributed to students not retaining the skills which should have been developed during the previous assessment items. This led to dissatisfaction with the course resulting in a mean Quality Learning Experience (QLE) rating of 3.8/5 and 77.8% satisfaction with the course in 2018/2019. Due to this MECH1110 was identified as a course that demanded improvement, where the authors determined that this was not a technology issue, but rather a pedagogical issue.

Since the implementation of a portfolio-based assessment approach, recent CES data for MECH1110 suggests excellent overall student experiences resulting in an average 96.9% satisfaction with the course. This is well above targets set at the University of Newcastle and also well above the averages in the data shown in *"Figure 1 - The undergraduate student experience, 2017-2022 (% positive rating)"* from the 2022 Student Experience Survey (SES) national report (QILT, 2023, p.4).The feedback and support from our students regarding the Q&A Forums has also been exceptional, reflected in the level of student satisfaction with MECH1110 showing significant changes in CES data from an average of 3.8/5 before 2020 to an average of 4.7/5 since 2020 (as shown in Figure 5). It is important to note that some (less than 2% of total student cohort) provided minor negative feedback around the time it could take for marking/feedback to be provided during the tutorial sessions. This was ultimately attributed due to either resourcing restrictions or students not engaging in the process, rather than the method of a portfolio assessment approach.

One of the most remarkable observations from the implementation of the portfolio-based assessment approach in MECH1110 was the level of student experience satisfaction for 2020 in comparison to the data presented in the 2022 Student Experience Survey (SES) national report (QILT, 2023).

> *"There was a sharp reduction in students' ratings of their educational experience in 2020. Ratings improved somewhat in 2021 and again in 2022, as institutions and students have adapted to changing teaching and learning environments."* (QILT, 2023, p.2).

The 2022 SES national report (QILT, 2023) outlined that the 'Quality of entire educational experience' in 2020 was at the lowest value of 68.7% (from the recorded data) and this was mainly attributed to a reduction in satisfaction of 'Learner Engagement' (44.5%) and 'Learning

Resources' (76.0%). Further to this when engineering undergraduate student experience ratings are considered, the 'Quality of entire educational experience' in 2020 was even lower resulting in a value of 61.0% (from the recorded data) and this was again mainly attributed to a reduction in satisfaction of 'Learner Engagement' (47.8%) and 'Learning Resources' (71.7%). When the implementation of a portfolio-based assessment approach in MECH1110 is considered, the 2020 CES data suggests excellent overall student experiences resulting in 100% satisfaction with the course. This was directly attributed to the implementation of the methods outlined in this paper which saw the development of exceptional learning resources which fostered student learning and engagement.

Conclusion

This paper has presented a portfolio-based assessment approach which has shown to have significant potential for any skill-based course. In the MECH1110 implementation, student satisfaction and increases in average grades was realised. The use of a portfolio assessment methodology resulted in 96.9% satisfaction with the course, well above targets set at a regional Australian University and well above the averages shown in *"Figure 1 - The undergraduate student experience, 2017-2022 (% positive rating)"* from the 2022 Student Experience Survey (SES) national report (QILT, 2023, p.4). Further to this, engagement and student learning outcomes dramatically rose with an increase in average marks as shown in Figure 4. These results are primarily attributed to the weekly portfolio-based assessment regime, continual feedback provided to students and support students received in tutorial sessions, which resulted in greater student engagement and motivation in their studies.

References

Flores, M.A., Simão, A., Barros, A. & Pereira, D. (2015). Perceptions of effectiveness, fairness and feedback of assessment methods: a study in higher education. *Studies in Higher Education,* 40(9):1523-1534.

McMullan, M. (2006). Students' perceptions on the use of portfolios in pre-registration nursing education: A questionnaire survey. *International Journal of Nursing Studies,* 43(3):333-343.

Nicholson, D. (2021). Integrating flexible assessment for inclusion. #LTHEChat 202. https://espace.mmu.ac.uk/627971/

Payne, R. N., Bramhall, M. D., Lawson, J. S., Robinson, I. & Short, C. (1993). Portfolio assessment in practice engineering. *International Journal of Technology and Design Education,* 3(3):37-42.

Räisänen, M., Postareff, L. & Lindblom-Ylänne, S. (2021). Students' experiences of study-related exhaustion, regulation of learning, peer learning and peer support during university studies. *European Journal of Psychology Education*, 36(1):1135–1157.

QILT (Quality Indicators for Learning and Teaching). (2023). 2022 Student Experience Survey. *2022 Student Experience Survey (SES) National Report.*

Quinton, S., & Smallbone, T. (2010). Feeding forward: Using feedback to promote student reflection and learning: A teaching model. *Innovations in Education and Teaching International*, 47, 125–135.

Taylor, B., Harris, L.R. & Dargusch, J. (2017). Portfolio assessment in Engineering: Student perspectives on effective implementation. *International Journal of Quality Assurance in Engineering and Technology Education*, 6(2):1-21.

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