34th Australasian Association for Engineering Education Conference
3 - 6 December 2023 – Gold Coast, QLD

Formative Sprints to improve feedback, learning, and fidelity in practice-based activities

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CONTEXT
The success of Engineering graduates transition to professional practice depends on the achievement and application of both their technical and professional competencies (Scott and Yates 2002). To ensure the integration and the development of these skills, there has been a move to incorporating more practice based and authentic contexts in engineering education.

Mechanical Design Fundamentals Studio 1 is the first studio undertaken by mechanical and mechatronics engineering students in their 2nd year at University of Technology Sydney (UTS). The primary objective is for students to collaborate in teams to achieve the goals of the Warman Design and Build Competition (Warman Design and Build Competition, 2023). This studio is an opportunity for students to apply the theoretical knowledge they have learned from previous subjects to a real-world engineering challenge. Through involvement in the competition, they will develop essential skills in the design process and project management while developing and demonstrating creativity, teamwork, communication, and problem-solving abilities all critical for successful engineering practice (Male et al. 2009).

PURPOSE OR GOAL
The investigation explores the correlation between the indicative grade level of formative assessment and the portfolio grade and to what extent students used the formative feedback from the Sprints to improve their learning and achievement as demonstrated in their final portfolio.

APPROACH OR METHODOLOGY/METHODS
In Agile methodology, "a sprint is a set period of time where all the work is done." A series of task-related formative "Sprints" are used "to motivate everyone by defining an outcome and a clear plan for success" Atlassian (2023). In Mechanical Design Fundamentals Studio 1, the intention of formative sprints is to increase authenticity, assessment fidelity, guide students learning and provide feedback. In each sprint students undertake design exercises that contribute to their final portfolio. During and after each sprint feedback is provided by studio facilitators. Students are expected to reflect on, respond to, and use feedback to make improvements as they are working towards their final submission. A random sample of students from each grade of the portfolio (fail to high distinction) was chosen for the investigation. Students' feedback from each sprint and their final submission were reviewed and coded to identify the different characteristics of evidence.

OUTCOMES
The formative Sprints were effective in promoting student engagement, reflection, and the use of feedback for improvement, developing their feedback literacy (Carless and Boud, 2018). While their formative nature increased assessment fidelity (Sadler, 2010).

CONCLUSIONS/RECOMMENDATIONS/SUMMARY
The use of integrated achievement formative Sprints into practice-based learning activities facilitated feedback for learning and improvement, leading to increased demonstrated learning achievement. Importantly, without reducing the fidelity of the subject's assessment activities.

KEYWORDS
Authentic learning and assessment, Assessment fidelity, Feedback, Feedback Literacy

Introduction

Mechanical Design Fundamentals Studio 1 is the first studio undertaken by mechanical and mechatronics engineering students in their 2nd year at University of Technology Sydney (UTS). Students work in teams to achieve the goals of the Warman Design and Build Competition) that challenges students to develop practical mechanical engineering solutions to theoretical problems (Warman Design and Build Competition, 2023). It is an opportunity for students to apply their theoretical knowledge from previous subjects to a real-world engineering challenge and develop essential skills in the design process and project management while developing and demonstrating creativity, teamwork, communication, and problem-solving abilities.

The studio-based learning environment used to facilitate this activity is student-centred and focuses on active learning. Students undertake a 12-week design project facilitated through three-hour studio sessions held in workshop environments each week of the semester. Research from Prince and Felder (2006) supports active learning, whereas traditional teaching and learning are often transactional and used in teaching engineering technical subjects, the complexity of modern design challenges, e.g. designing a transporter system such as in the Warman competition, are not amenable to lectures and tutorials with problem-based learning as if there is a single right answer. Primarily, the key skills are design orientation, collaboration, and the development of skills to manage complex design tasks. Studios are experiential learning opportunities, and this approach aims to help students optimise their learning experience and better develop skills that help them to adapt to the professional world of engineering (Charosky et al, 2022). Professional skills developed include communication and interacting in teams in ways that achieve set goals and success. Self-direction, reflective thinking, clear communication, ability to contribute advice, seek feedback and use this feedback to reflect and improve on their own ongoing development is developed through a carefully planned 12-week schedule.

To provide a scaffold for students to succeed in this subject the 12-week semester is divided into 4 sprints, each held in blocks of three consecutive weeks. At the end of the semester, students submit a portfolio that consists of four artifacts demonstrating their individual contributions to a team design project. Formative Design Exercises (DE) with indicative grades have been packaged to guide students between sprints on their individual learning paths and are submitted at the end of sprints 1,2 and 3. Engaging with the design exercises assists students in creating artifacts for their portfolio and helps them build on previous knowledge and create new knowledge and understanding that is applied to individual learning and the team project. An artifact in the context of this studio is a student's individual piece of work where the student has applied engineering principles to create a detailed design of a component that supports the complete system. An example of a mechanical artifact may include developing a lifting mechanism such as a scissor lift, whilst mechatronic artifact may involve motor selection, pseudo-code, and benchtop testing. Projects that are complex, having an infinite number of solutions, require students to use their judgment to manage multiple possibilities, and competing demands, use testing, critical evaluation, and reasoning to arrive at their proposed solution (Willey and Machet 2018, 2019). As such, the learning activities in this studio subject provide students with an opportunity to develop their skills to manage complexity.

Another key element of engaging in the sprint activities is for students to record their progress, and their ability, to seek, receive, and reflect on feedback to inform learning and improvement. The students record this in their Engineering Design Journal. Our intention is for these entries to support critical thinking, problem-solving skills and to promote personal growth in the field. In the workplace, an engineering design journal, also referred to as an engineering logbook or notebook, serves a critical role in ideation, record keeping, and communication as it can help stakeholders understand the work completed by colleagues and their role in the work produced (Kelly, 2011).

The studio curriculum design provides a well-scaffolded expectation of students needing to be proactive participant learners. Students are encouraged to use feedback to make sense of information from various sources and use it to enhance and improve their work and learning (Carless and Boud 2018). Feedback literacy described by Carless and Boud (2018, p.1315) as “the understanding, capacity and dispositions needed to make sense of feedback and use it to enhance one’s work and learning” is predicated on students using the feedback to take action. The guidance, coaching and modelled environment provided through the studio interactions and discussions with other students and instructors assists students to develop their judgement and manage their affect reactions to feedback to both improve their learning, demonstrated achievement and develop their feedback literacy skills. To do so, students need to develop the capability to make decisions about the quality of their own work, and the work of others, referred to as evaluative judgment (Tai et al., 2017).

The use of assignments where students must make ongoing judgments about the quality of their work, through a requirement to plan, draft, evaluate and re-draft their work, generates internal feedback (Butler and Winne,1995). This analogy was used in the design of the formative design exercises in this studio which provide students with external feedback so they can refine their work throughout the semester. By giving students the opportunities for self-evaluation and comparison over an extended time they can improve judgment (Boud, Lawson, and Thompson, 2013, 2015). It is also useful to think about rubrics as self-regulation (Winstone and Carless 2020). By making criteria explicit, rubrics can support the appreciation of feedback to understand what is required to improve (Jönsson, & Panadero, 2017).

At the end of Sprint 1 students submit Design Exercise 1 (DE1) which is less related to the final portfolio, however, it is crucial for students to build their skills in CAD modeling, drawings, and appropriate use of AS1100, that are assessed in the artifacts in the portfolio. Students have access to a detailed rubric and receive detailed written feedback in addition to what the rubric provides. The feedback informs students where they need to improve these skills. At the end of Sprint 2 students submit Design Exercise 2 (DE2) which guides students on how to create their first comprehensive mechanical artifact that will be included in their final portfolio submission. In addition to the indications in the rubric, students are provided with comprehensive written feedback to improve and/or expand the artifact. They then have an opportunity to discuss further with peers and mentors in class. At the end of Sprint 3 students submit Design Exercise 3 (DE3) where they are asked to resubmit the improved DE2 artifact together with two additional artifacts. Student’s competency and areas of improvement are highlighted in the rubric, as well as being provided with comprehensive written feedback to help them improve their artifacts for their portfolio. In the portfolio there is a final fourth artifact for which students must seek advice and feedback in class. The fourth artifact also relies on students considering and using the feedback provided for the earlier artifacts, which mainly relates to how to structure an artifact or technical aspects such as drawing standards.

The aim of this study is to explore the correlation between the indicative grade level of formative sprint exercises and the portfolio grade and to observe the extent to which students used the formative feedback from the sprints in their final portfolio. This paper reports on the results of an investigation to determine the impact on student learning and demonstrated success of their engagement with feedback provided throughout these formative sprints to support future teaching and studies in student feedback literacy.

Methodology

In Mechanical Design Fundamentals Studio 1 letter grades are used with the following description: Fail (Z) 0-49%, Pass (P) 50-64%, Credit (C) 65-74%, Distinction (D) 75-84%, and High Distinction (H) 85-100%. Design exercises are formative and do not contribute to a student’s final grade. They indicate the quality of a student’s submitted work and their level of demonstrated achievement by providing an indicative letter grade. The letter grades were coded into numbers to enable data processing as Z=0, P=1, C=2 D=3 and H=4. The portfolio score is given out of 100.

Trends of DE1, DE2 and DE3 indicative grades were compared with the portfolio grades to investigate the impact of engaging with formative assessment in Mechanical Design Fundamentals Studio 1. This study includes the 269 students (n=269) available in the grade center on Canvas, which includes non-completing students in the data set. The data also includes non-submissions of design exercises which are reflected as failing grades in the data for the design exercises. It was chosen not to remove these from the data as it displays the extent of student non-engagement across the grades in the different exercises.

In order to mitigate potential effects of sampling bias caused by non-submissions in the statistical analysis, a randomized selection of 5 students in each portfolio grade category (Z, P, C, D, H), (n=25), excluding any non-submissions was used.

Data Analysis

To determine if the grades of DE1, DE2 and DE2 were correlated with the portfolio grade a generalized model (GENMOD) considering Wald Statistics for Type 3 GEE was used to test students' participation and engagement with the formative assessments. The statistical program SAS (Statistical Analysis System Inc., Cary, USA, vers. 9.4) was used. The data were normally distributed and $p<0.05$ was considered as significant.

Results

Impact of Formative Assessments on Portfolio Grade

The overall submission trends between DE1, DE2, DE3 and the portfolio suggests that the number of submissions for the design exercises and their grades follows a similar pattern as the portfolio (Figure 1). It can be seen that DE3 has the largest number of Z-grade submissions, which also includes non-submissions which were not removed from the data set. The gap between the grade for DE3 and portfolio, suggest that many of those non-submissions ended up with a portfolio grade other than Z. To get a better understanding on what the distribution was for each design exercise, more detailed results of the individual submissions for each design exercise and portfolio are displayed in Figures 2-4.

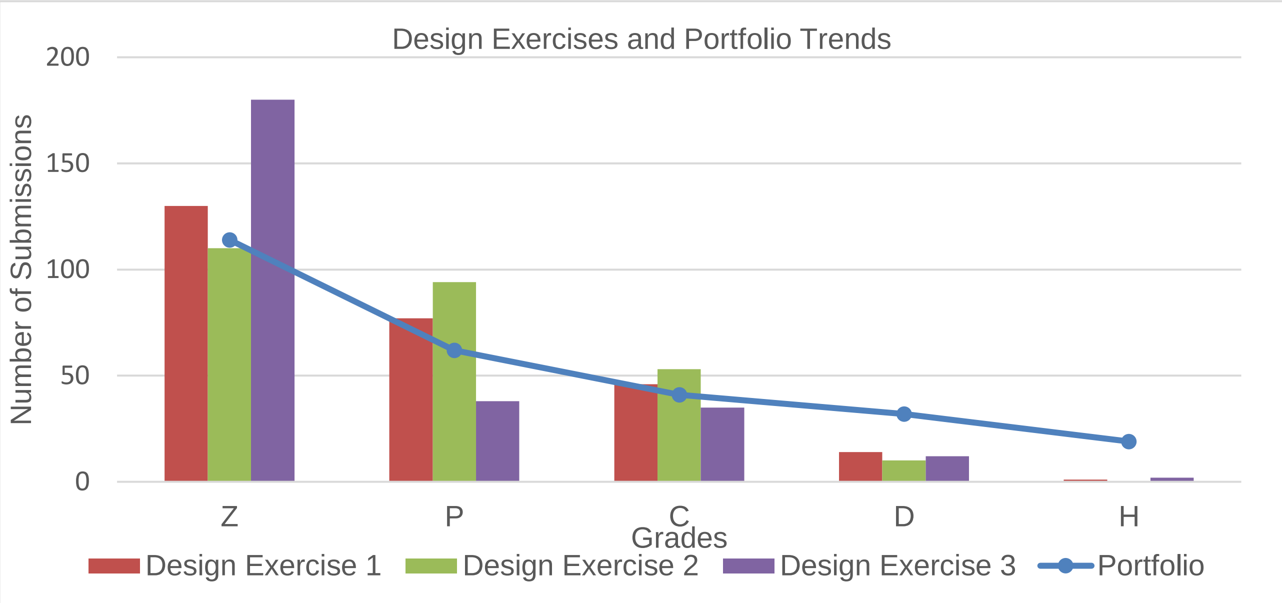

Figure 1. Trend of number of submissions with corresponding Z, P, D, and H grades for the design exercise and portfolio. The data includes non-submissions for the Z grade.

In Figure 2 the DE1 indicative grade compared to the portfolio grade is shown in ascending order for portfolio grades. From the DE1 submission it can be observed that students achieved between Z to C level grades, with outliers achieving D. The moving average indicates that there is a positive trend in the level of suggested grade for DE1 and the portfolio grade or rather the frequency of suggested grades for students that achieved, particularly those who scored 55 points or more for their portfolio. It can also be seen that those scoring lower than 55 points in the portfolio were less likely to achieve a C level submission for DE1 and a lot more Z level submissions, which indicates either low effort or non-submissions.

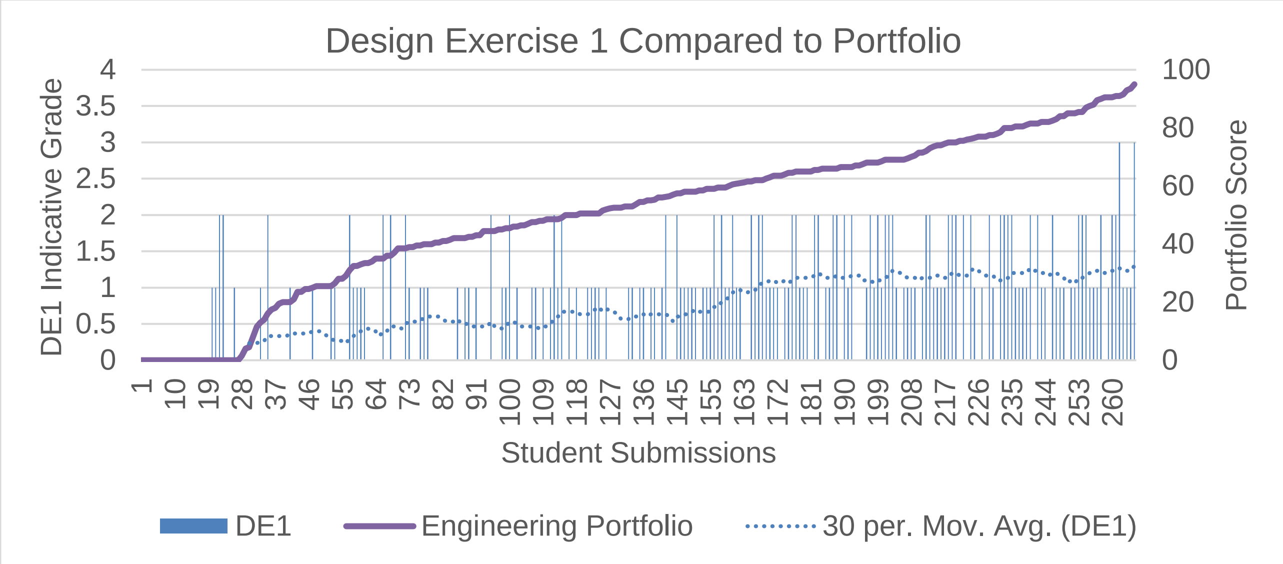

Figure 2. Students' indicative grades for design exercise 1 compared to their portfolio score (n=269 students).

In Figure 3 the student submissions of DE2 indicative grades are compared to the portfolio scores in ascending order for portfolio score. From the DE2 submission, it can be observed that students achieved between Z to D level grades, with an outlier achieving H. The moving average indicates a stronger positive trend in the level of suggested grade for DE2 and the portfolio grade than what is observed for DE1 in Figure 2. Similarly, there is also a higher frequency in submission attempts and suggestive grades for those who scored 55 points or more for their portfolio. It can also be seen that those scoring lower than 55 points in the portfolio were less likely to achieve a C level submission for DE2 and a lot more Z-level submissions which indicate either low effort or non-submissions.

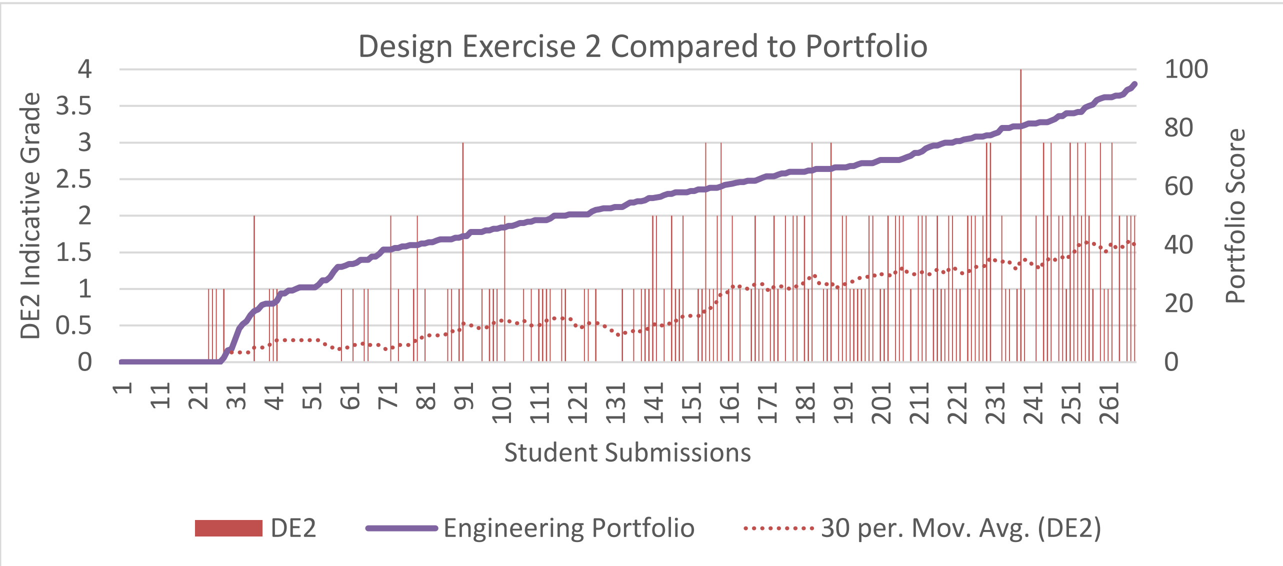

Figure 3. Students' indicative grades for design exercise 2 compared to their portfolio score (n=269 students).

In Figure 4, the student submissions of DE3 indicative grades are compared to the portfolio in ascending order for portfolio score. From the DE3 submissions it can be observed that students achieved between Z to D level grades, with two outliers achieving H. Those outliers also scored above 85, which mean they were H level students. The moving average indicates a similar positive trend in the level of suggested grade for DE3 and the portfolio grade than what is observed for DE2 in Figure 3. There is also a higher frequency in submission attempts and suggested grades for those who scored 65 points or more for their portfolio, indicating more effort taken by C level students and above. It can also be seen that those scoring lower than 65 points in the portfolio were less likely to achieve a C level submission for DE2 and a lot more Z-level submissions which indicate either low effort or non-submissions. Overall, the graph also shows that more students received a Z, as observed in Figure 1, this is likely linked to the number of non-submissions recorded as Z grades for DE3.

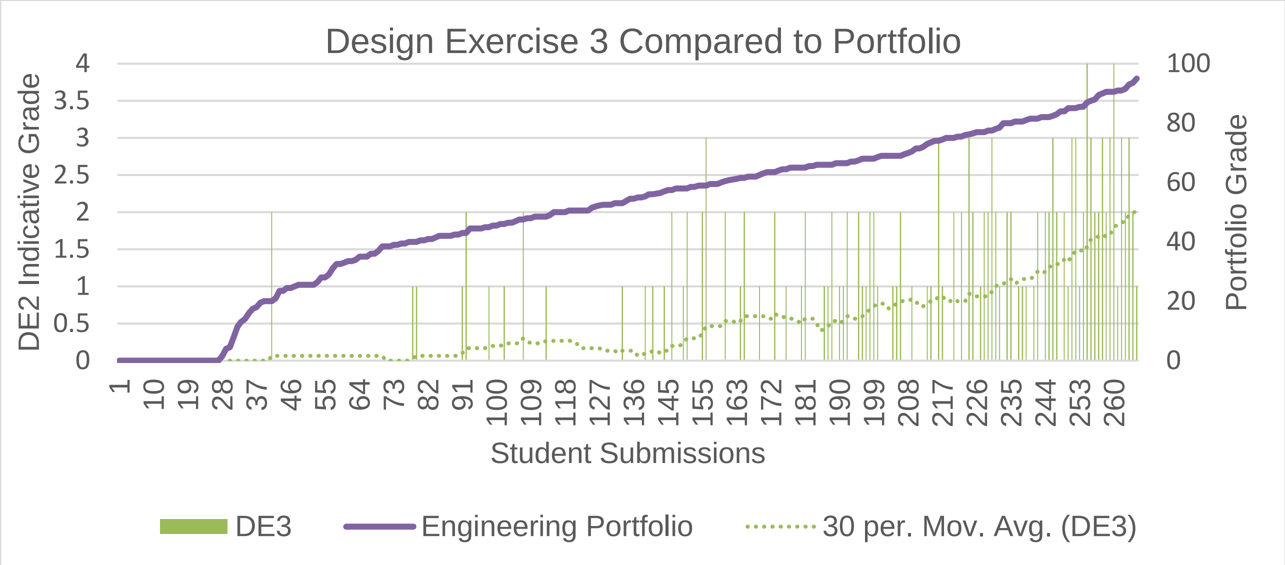

Figure 4. Students' indicative grades for design exercise 3 compared to their portfolio score (n=269 students).

When the whole cohort is considered, the portfolio grades are significantly affected by DE1 (Table 1). Whilst when limiting the data set and considering the sample of 25 students, all with submissions made for the design exercises, the portfolio grades are not significantly affected by DE1. For DE2 and DE3 on the other hand, both have a significant correlation with the portfolio grade for the cohort as well as the sample of 25 students. Whereas DE3 has the strongest effect on portfolio grades. This confirms the trends observed for the cohort in Figure 2-4, as it can be observed that students with higher grades are more likely to submit and receive a grade for the design exercises.

The impact of DE2 and DE3 on the portfolio is a lot more similar for the randomly selected students than the cohort, which may be due to the potential non-submissions. The degree of freedom (DF) indicates that none of the 25 randomly selected students achieved a HD in DE2 or DE3.

Table 1. Wald Statistics for Type 3 GEE Analysis of indicative grades for design exercise on the portfolio grade for the cohort (269) and randomly selected students (25) across the five possible grades.

	269 Students			25 students		
Source	**DF**	**Chi-Square**	**Pr > ChiSq**	**DF**	**Chi-Square**	**Pr > ChiSq**
DE1	3	27.64	<.0001	3	7.00	0.0719
DE2	4	36.73	<.0001	3	8.79	0.0322
DE3	4	78.17	<.0001	3	8.81	0.0319

Discussion

The results suggest that there is a strong relationship between the indicative grades for the design exercises and the final grade for the portfolio. This indicates that the indicative grade for the design exercises is a reliable predictor of a student's final grade. The intended purpose of the formative design exercises is to improve student learning via engagement, which means the design exercises can be used to identify and prompt students that are underperforming earlier in the semester to motivate change.

That DE2 and DE3, and the portfolio grade have the strongest correlation between the predicted and final grade, agree well with them being designed to create a draft of the portfolio, whilst the main purpose of DE1 is to obtain technical skills in CAD and drawings. It is only when removing sample bias of non-submissions which neglect that there was a decline in overall submission numbers from DE1 and DE3 it is observed that DE1 no longer has a significant correlation with the portfolio grade as observed by the lower Chi-Square results. Removing the sample bias more accurately reflects the role of the design exercises for those students who completed them. Further investigation into how those technical skills and students' ability to use the feedback given to create quality artifacts in their portfolio is required.

Throughout the progression of the sprints, students were less likely to engage with the formative design exercises. The frequency of submission can be found to be reduced, and its particularly evident that students with portfolios below a passing level are less likely to submit the design exercises.

To understand students' critical engagement with the design exercises through the sprints, and their level of feedback literacy, the design exercises, portfolio, and engineering design journals were reviewed to investigate common characteristics. The key difference between students' characteristics across the different grades was their ability to actively use and seek feedback to improve their work. The engineering design journals highlight that high-achieving students are feedback literate and able to critically engage and respond to feedback via action in a manner described in the framework proposed by Carless and Boud (2018). However, the lower achieving students are less likely to effectively engage with the feedback as active learners. As such, there is a potential correlation between students' ability to critically engage with feedback and the overall grade of their portfolio.

The formative design exercises provide students with external feedback so they can refine their own internal feedback. External feedback that focuses on supporting students to refine their own internal feedback has more impact on learning than conventional feedback which is seen as “telling” according to McConlogue (2015). This suggests that further consideration may need to be taken in the communication to students about the role of feedback and their engagement with the feedback process e.g. studies like this, enable academics to provide evidence of the importance of the feedback to students and explain their role as active learners. Instructors are responsible for preparing students with strategies to take productive action on feedback, while students carry the responsibility to engage with and use feedback (Nash and Winstone 2017).

It is also worthwhile to consider the role of rubrics as means of feedback other than personalized written feedback. Rubrics, grade descriptors, or lists of criteria can be helpful in clarifying expectations but academics and facilitators need to promote some form of student engagement with these criteria. This is challenging because rubrics need careful consideration in design. In Mechanical Design Fundamental Studio 1 rubrics are used to help students understand their competency level and indicate the quality of their work. According to Royce Sadler (2015), providing rubrics in advance may inadvertently inhibit holistic student appraisals of quality. Students were provided with rubrics for DE1, DE2 and DE3 as the exercises are made available and the portfolio contains a rubric that considers the quality of the artifacts and the ability to align with the rubrics provided in the design exercises. It would be useful to investigate the impact of rubrics and their role in feedback literacy by completing further studies, particularly to further develop means of improving student feedback literacy, but also as means to provide meaningful feedback more efficiently for large studio cohorts.

Non submissions

It was observed that several students chose not to submit the formative design exercises. When considering the impact that the indicative grades of the design exercises have on the portfolio, it is likely that the grade for students choosing not to submit could be overall lower compared to if they had submitted the design exercises. Another viewpoint is that those who decided not to submit the design exercises in the formative sprints were unable to critically engage in order to receive feedback and as such were also not able to appreciate the feedback process nor make accurate judgement about the quality of their work as they didn't take the opportunity. These are two critical aspects of feedback literacy included in the framework presented in Carless and Boud (2018).

From informal conversations, several students said they would have been more inclined to participate in the formative sprints if they were given even a few marks for doing so. Academics often use and students often expect mark inducements to motivate participation. This often results in marks accumulated for work that is below the level of demonstrated satisfactory achievement, meaning that students receive recognition for work despite poor quality. Sadler (2010) describes fidelity “as the extent to which elements that contribute to a course grade are correctly identified as academic achievement”. Fidelity is reduced through awarding marks for submissions of early understanding. Doing so not only increases academic workload, but distorts the relationship between a student’s final grade and their level of demonstrated academic achievement expected at the end of a subject.

This does suggest that more needs to be done to develop students' and academics' feedback literacy. Academics need to clearly scaffold to students the intent of their learning activities and how to achieve the potential benefits (Carless and Boud, 2018; Boud and Dawson, 2023; Carless and Winstone, 2023). Students need to see feedback as more than telling them how to improve but is something that requires them to be proactive in both seeking and responding to feedback and actively integrate it into their learning process. UTS is currently undertaking steps to improve feedback literacy in future studies we will endeavour to investigate whether this has had a positive impact on student participation in and benefit from the formative sprints.

From reviewing the student submissions, the student feedback survey, and informal conversations, there were indications that the workload from the subject together with other subjects is overwhelming. Student’s contribution in time spent on tasks reduce towards the later part of the semester, a reason may be due to new curriculum changes where the technical subjects hold mastery quizzes in weeks 7-9, whereas DE3 is due in week 9. To properly understand the impact of this scheduling further studies would need to be undertaken. However, these observations suggest the care needs to be taken to avoid curriculum crowding and that feedback processes should be embedded into existing activities rather than being standalone or seen as additional.

Conclusion

From the findings, it is evident that submission contribution in formative assessments and the ability to respond positively to feedback has a significant impact on students’ ability to achieve higher grade through improved demonstrated achievement in their portfolio submissions. From a demonstrated learning perspective, it gives a clear reason to support why students should actively participate in the Sprint formative assessments. There is a need to change student culture, so they see feedback as more than just telling, to be used for improvement not just correction and to remove an expectation of reward or marks to undertake formative work or learning. Being able to support claims with findings such as those reported in this paper, may assist instructors in demonstrating to students that their participation and contribution is rewarded despite not receiving marks that contributes to their final grade. To help students navigate feedback opportunities as provided, facilitators recognise the importance of continuously connecting with students to maintain communication as well as to scaffold activities by breaking them down into smaller parts.

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