



A MATHEMATICS PEER ASSESSMENT PROCESS FOR FLEXIBLE MODES OF DELIVERY

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ABSTRACT

Educators have experienced significant challenges managing assessment processes over the last two years, particularly when converting in-person interactive and group-based activities to an online format. This was of immediate concern during the initial stage of the Covid-19 pandemic, when interim measures for online assessment were introduced rapidly without the benefit of prior planning and design. As we emerge from the emergency phase of the pandemic, it appears there will be lasting changes to delivery and assessment in higher education, involving more hybrid and blended solutions. This paper discusses how an on-campus peer feedback assessment process for mathematics has been converted to a digital format to facilitate flexible modes of delivery either on-campus or online. A weekly paper-based peer-feedback process had been previously established in our large (150+) first-year engineering mathematics class. The new process involves weekly submission of work through the university Learning Management System (LMS), Canvas, which is peer marked by students using model video solutions for selected questions. Students complete a rubric and provide comments. After each session, students complete a reflective journal, considering their work over the week and the comments they have received. Engagement with the new flexible process has been shown to be comparable to the old system, while the quality of feedback given to peers in the online process is superior to those provided in the paper-based system. The system has been shown to be robust when rapid changes in delivery modes occur.

1 INTRODUCTION

1.1 Peer assessment and reflection

Peer assessment has been used as a tool across a number of disciplines to encourage students to think about how assessments are evaluated and make critical judgements about quality of work [1], and has been considered to be a fundamental

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skill that graduates will need in their future careers [2]. A number of studies over the years have highlighted the benefits for students in engaging in peer review and assessment processes in mathematics. These include developing critical thinking skills, increasing agency over their own learning and improving outcomes [3-5].

1.2 Context of module and the assessment process

The stage 1 mathematics module in the School of Mechanical and Aerospace Engineering is a large core module, typically with 150+ students, taken by all year 1 students from the mechanical, aerospace and product design engineering pathways. Prior to the onset of the Covid-19 pandemic, the module was delivered by means of a traditional two-hour lecture, followed by a one-hour “feedback session”. The feedback session format was developed and introduced in the 2016-17 academic year [6] and involved students completing weekly worksheets in a logbook, then attending a session where they worked in a small group. At the feedback session some model answers were demonstrated on the board, and students marked their peers’ work, making some comments. After the session, students wrote a short weekly reflection, and at the end of the year submitted their entire logbook along with a longer reflection piece. This process worked well for several years as an in-person activity that encouraged weekly participation, interaction with peers and active learning. This continuous assessment element contributed 40% of the module mark, with the other 60% from a final examination. The continuous assessment element was intended to evaluate the ability of the students to reflect on their own work and make improvements, and develop their transferable skills over the year such as technical communication and groupwork, while the examination tested their mathematical ability (Table 1). For this reason, it was compulsory for students to pass both elements in order to pass the module.

Table 1: Assessment weighting and major learning outcomes

Continuous Assessment	Written Exam
Based on submission of worksheets, reflections and contribution to peer feedback	End of year
worth 40%	worth 60%
Tests Learning Outcome: evaluate and reflect on the quality of your work and learning.	Tests Learning Outcome: identify and apply appropriate mathematical techniques for solving engineering problems
Formative and summative	Summative

After the rapid switch to online learning due to the Covid-19 pandemic, an interim solution was developed to allow the students to carry out the peer review process online using groups on MS Teams during the 2020-21 academic year. Several key issues were identified during the year, including the fact that the process was cumbersome for students, not all students engaged well and monitoring of this was very difficult for academic staff, and marking at the end of the year was extremely challenging as there were a large number of documents to look at for each student. However, a clear benefit of the process was that the quality of the feedback left by



students for their peers was very high, with many leaving detailed and helpful comments every week. This contrasted with the short handwritten points that students had previously tended to make in the paper-based logbooks.

2 METHODOLOGY

2.1 Development of a new flexible process

In September 2021, the university returned to full in-person teaching for the first time since the pandemic. While issues had been found with the online peer-review process, it was not possible to return to using the old paper-based method for three reasons:

1. There were clear health and safety concerns with students sitting in close groups and passing physical logbooks around the group.
2. There was a high probability that some students would be self-isolating at different times throughout the year and so would be unable to meet their groups in person.
3. There was a possibility that teaching staff would contract Covid-19 and so would need to teach from home, or that the campus would close for a period of time and teaching would revert online.

It was also recognised that students generally spent more time writing longer and more detailed feedback comments when working digitally than they would have previously handwritten in books, and so it was felt it was desirable to retain this.

The first consideration was how to structure the assessment and determine what systems needed to be put in place for the 2021-22 academic year. In order to address the issues found with the interim online system, and the three concerns listed above, the decision was taken to manage all submission of worksheets and peer marking online, but to use the university Learning Management System (LMS), Canvas, to manage this. Students were required to submit their scanned worksheets to Canvas each week by 9am on the day of the feedback session, and were then randomly assigned three anonymous peer worksheets to review. Students could attend a computer suite, or an assigned groupwork room if they preferred to use their own devices. Students who were unable to attend in person due to self-isolation or for other reasons could access their assigned peer reviews from home. As students were working across different locations, pre-recorded video worked examples were provided, which were only made available for the duration of the feedback session via the LMS. Using the video exemplars, and through conversation with their peers and the session facilitators, students were required to give feedback by completing a rubric (Table 2) and by writing comments about the work. The set of peer scores received by each student each week was reviewed by the lecturer, any outliers in scoring were moderated, and an average value returned. This provided ongoing weekly feedback to students. Guidance was provided to students to ensure they understood that the aims of giving feedback were to be constructive and to provide opportunities for improvement, and that the benefits to themselves included: receiving regular feedback on their own work, learning from looking at others' work,



developing independent learning, recognising their own strengths and weaknesses, gaining opportunities for active learning and improving reflection and communication skills.

Table 2: Rubric for peer scoring

	3	2	1	0
Effort	Clear evidence of effort in answering (even if not correct)	Good effort in answering but room for improvement	Some effort, but not satisfactory	no effort
Correctness	All correct	Mostly correct with some small errors	Mostly incorrect	no effort
Coherence	Method can be followed very clearly (even if answer not correct). Excellent annotation, notation and clear steps	Method can mostly be followed, a few steps missing or would benefit from better annotation or notation	Difficult to follow method, unclear working (even if correct)	No effort
Conciseness	Method used is appropriate and very efficient	Method is appropriate but could be simplified	Method is overly complicated or long	No effort

After the session, students transferred the reviews they gave and received into a “reflection journal”, a template for which was provided, and wrote a weekly reflection consisting of around five bullet points. There was an optional opportunity for students to submit their “work-in-progress” to the lecturer for formative feedback in the middle of semester 1, to ensure that their work was at an appropriate level. At the end of each semester students were required to write a 500-word summary reflection and submit the whole journal for review by the lecturer. The breakdown of the final mark allocation for the continuous assessment piece is shown in figure 1, and includes marks for the quality of the student weekly and end of semester reflections (20 marks assessed by lecturer), the quality of feedback left by the student for others (5 marks assessed by lecturer), and the moderated peer scores discussed above (15 marks obtained from scaling the sum of each student’s moderated and averaged peer reviews).

In the original paper-based system there was a requirement for students to attend a minimum of 75% of the peer review sessions to ensure engagement. To allow for more flexibility in the 2021-22 year, and to take into account that students could be working remotely, this requirement was modified to require students to complete at least 75% of the work, i.e. submitting 15 out of the 20 assessed worksheets, and providing peer reviews on at least 15 out of the 20 sets assigned to them.

2.2 Data reviewed

Data was extracted from Canvas to show the number of submissions over the year and the number of peer reviews completed. The grades across the academic year 2021-22 for the continuous assessment element are compared with the final grades for the continuous assessment from the year prior to the pandemic.



Reflection journal							
Criteria	Ratings						Pts
Quality of weekly reflections on own work over the week	5 Pts	4 Pts	3 Pts	2 Pts	1 Pts	0 Pts	5 pts
- Commentary on how difficult or easy the work was	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- Commentary on particular areas of focus							
- Indication of time management							
- Indication of resources used							
Quality of weekly reflections on comments received from peers	5 Pts	4 Pts	3 Pts	2 Pts	1 Pts	0 Pts	5 pts
- Evidence that comments from peers are being read and reflected on	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- Commentary on whether you are learning from others' work or not							
- Evidence that you are identifying areas of improvement or areas of your own good practice as appropriate from the peer feedback							
Quality of end of semester reflection	10 Pts	8 Pts	6 Pts	4 Pts	2 Pts	0 Pts	10 pts
- Commentary on what problems have you encountered and how have you dealt with them?	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- What was especially satisfying to you about either the process or the finished piece of work?							
-What does your work this year reveal about you as a learner?							
-Have your goals changed as you have progressed through the module?							
-How have you used the feedback received to improve your work?							
-What have you seen in other students' work or learning that you would like to try in your next module?							
-How have you contributed to the group in the feedback sessions?							
-Looking back at this module, what would you like to try to improve?							
-How confident are you that you will pass this module?							
Quality of the peer feedback you left for others	5 Pts	4 Pts	3 Pts	2 Pts	1 Pts	0 Pts	5 pts
Is your feedback:	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- Constructive?							
- Specific?							
Does your feedback:							
- Offer opportunities for improved performance?							
- Show that you are reviewing the work carefully?							
Worksheets (from peer reviews)	15 to >11.0 Pts	11 to >9.0 Pts	9 to >7.0 Pts	7 to >6.0 Pts	6 to >0 Pts		15 pts
	Excellent	Very good	Good	Satisfactory	Unsatisfactory		

Fig 1: End of semester rubric (marked by lecturer)

3 RESULTS

3.1 Engagement with the process

The engagement of students with the process was evaluated by comparing data from 2019-20, when the on-campus paper-based system was used, and from 2021-22 when the digital method was used. In 2019-20 there were 158 students in the class compared with 167 in 2021-22. Figure 2 shows the percentage of students who submitted each worksheet and the percentage who submitted the worksheet *and* completed their peer reviews. This is compared with the percentage of students who attended the sessions in 2019-20. Comparing the students who completed both tasks in 2021-22 (submitting worksheet and completing peer reviews) with the student attendance in 2019-20, it can be seen that the data is remarkably similar during the majority of first semester, up to worksheet 10. In the second semester some divergence is seen with the 2021-22 cohort having higher engagement in the early part of the semester, and lower engagement later. Overall, the average engagement per session was 89% with the paper-based, on-campus only system, and 88% with the digital system used in 2021-22, with students flexibly completing the work on campus or at home. It can be seen that the engagement was high for both years, with a minimum of 83% in both years, and a maximum of 96% in 2019-20 and 94% in 2021-22. It is worth noting that the module was taught by different lecturers in the two years, but engagement remained similar. This shows that using an online or blended system for carrying out peer review can work very well, and agrees with work carried out in other disciplines [7-8].



Figure 3 shows the number of students who completed different numbers of worksheets in 2021-22, and is compared with the number of students who attended a certain number of sessions in 2019-20. It should be noted that only 19 worksheets were provided in 2019-20, so the numbers have been scaled for comparison. It can be seen that almost half of all students completed all worksheets in 2021-22, while nine students (5%) failed to complete the minimum of 15/20 worksheets. It was also found that a further five students did not complete the required number of peer reviews despite submitting their own worksheets, resulting in 14 students (8%) overall failing the continuous assessment element. In 2019-20, eight students (5%) failed to attend the minimum number of sessions.

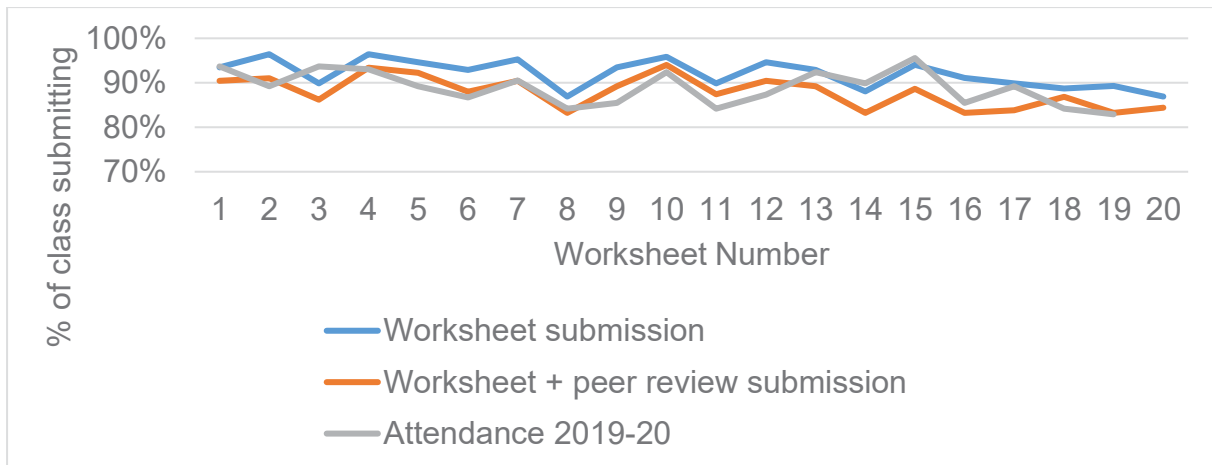


Fig. 2: Engagement with each feedback session

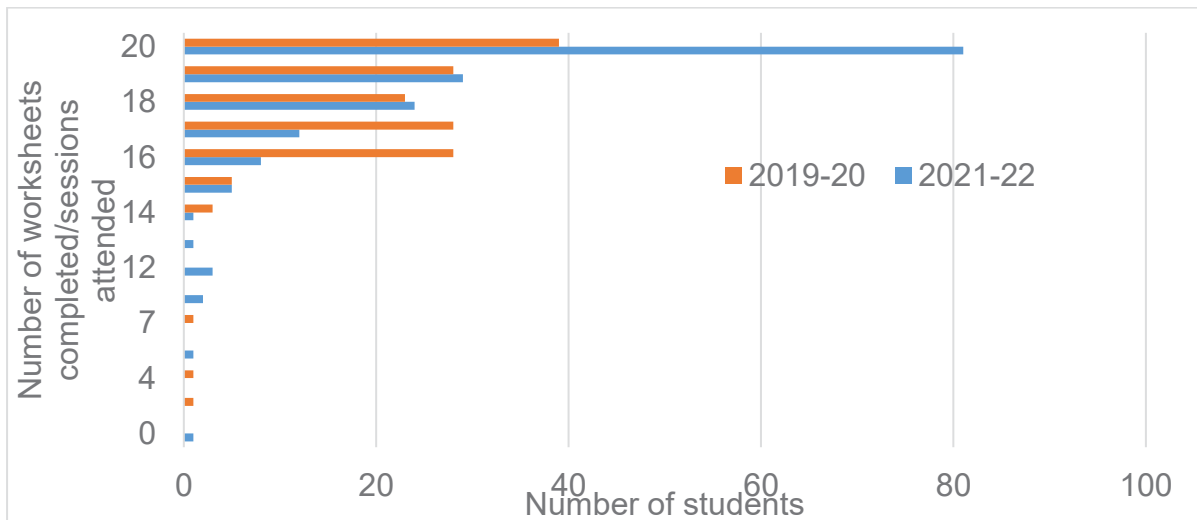


Fig. 3 : Number of students completing a given number of sessions

3.2 Grades across the year

115 students (68%) took the opportunity to submit their work-in-progress reflection journal for feedback in the middle of semester 1. The average formative grade awarded was 76%, with a standard deviation of 15%. Students were provided with rubric scores and feedback. The end of semester 1 summative submission had an average grade of 74%, with a standard deviation of 18%. The second semester submission showed an average grade of 66% with a standard deviation of 18.5%.



This drop was anticipated as semester 1 contains content that should mainly be revision to the students from their previous studies, whereas semester 2 content is likely to be new and therefore more challenging. Overall the final average for the continuous assessment was 69%, compared to a 58% average in 2019-20.

3.3 Student peer reviews

The average peer review scores given to each worksheet varied between 9.3 and 11.3 out of 12, with a standard deviation between 1.5 and 2.7 across the year. It was noted that there was good consistency across the worksheets, however, the scores are on the high side and may indicate lenient marking by the students, or an issue with poor differentiation by the rubric that was provided. This may need to be addressed next year to provide a better spread of marks. However, the peer scores contribute only 15 out of 40 marks and if they are extracted from the final marks for the continuous assessment, the overall average would drop to 64%.

3.4 Student comments for their peers

As found in 2020-21 when the peer review process was carried out online, it was clear that the students provided good quality feedback for others when working digitally in 2021-22. Some examples of student feedback are shown in figure 4.

9) correct answer found using appropriate method, well done. Be careful as when you wrote inverse= (matrix), you put a value of $-5/15$ for the element a_{12} . Whereas the correct value is $-5/18$. However, your working was clear so I was able to identify that you had found the value to be $-5/18$ previously and had simply made an error when writing, hence I haven't removed any marks.

Question 3 c is a very concise solution to the question with the correct answer. Well done. Question 5 e would have benefitted from a single additional step just before the final answer however it is all correct. Question 6 e gives the correct answer and an easy to follow solution. One change I would have made would be to explicitly reference the standard integral that you used. In question 8 d you have made a mistake regarding your partial fractions in obtaining $-1/2$ and 3 and values for the numerators. The correct answers were $2/2$ and 1 . Please try this question again as your integration was not what led to the wrong answer.

Figure 4: Examples of student peer comments

3.5 Adaptability and accessibility online and in person

As anticipated at the beginning of the academic year, there were times when students were unable to attend in person for various reasons including the fact that a substantial number of students tested positive for Covid-19 at various times across the year, the semester 1 lecturer tested positive for Covid-19 and delivered teaching online during the weeks corresponding to worksheets 7 and 8, and the university switched to a short period of online teaching during the weeks corresponding to worksheets 12, 13 and 14. It can be seen that during these periods the system continued to function as before with no discernable difference in engagement, suggesting that the process is robust and adaptable to rapid change. In addition, improvements in technology have made the process relatively straightforward to implement, compared to findings in earlier studies which found adapting peer review processes to online courses to be more complex and difficult [9].



3.6 Student feedback on process

Module evaluation surveys are issued to students electronically at the end of each module in the school. For this module, 57 responses were received (33.5%). Some freeform comments boxes were provided to ask students open-ended questions about what they found valuable in the module and what they would like to be improved. There were 35 comments about what students found valuable, 17 of these related directly to the peer feedback process, with students indicating it helped them to develop skills and to identify their strengths and weaknesses:

“The worksheets, along with the associated peer reviews, were very useful in developing my skills”

“The worksheets ... showed me not only what I knew but what I didn't know”

“I enjoyed the fact the assessment on the course was peer assessed as it allowed me to see how well my peers were coping with the module. It also allowed me to compare how well I was doing with the module”

There were 22 comments about areas that the students would like to see improved, with only four of these about the peer feedback process, mainly indicating that the quality of the feedback left by some students was not always helpful or accurate:

“Student feedback was mostly unhelpful. Students aren't well equipped to give valuable feedback. I found filling in my reflection journal very challenging, since the feedback I received was mostly bad.”

“I don't like the peer review / reflection journal. Sometimes, people marking my work understood the topic less than me and tried to correct things that did not need corrected. In my opinion maths should just be an exam, like in school.”

4 SUMMARY

Converting an in-person paper-based peer review process to a digital flexible format for a year 1 engineering mathematics module has shown that engagement with the process remained high, with at least 83% participation in each session in both formats. Similar percentages of students met the minimum attendance/participation requirements. Continuous assessment marks with the new system appear to be higher than with the previous system, some of which may be attributed to the fact that peer review marks may be overly high, and this will be looked at next year, however they contribute only a minor fraction of the overall mark. Quality of the comments left for students by their peers is higher in the new system, and student opinions of the process are generally positive. This type of process could be adapted across other mathematics modules, but also many other types of engineering module to provide flexible means of students accessing and participating in continuous assessment and peer review. As this is based on only one year of data, the process will continue to be monitored and adapted as appropriate.



REFERENCES

- [1] Falchikov, N, Goldfinch, J (2000), Student peer assessment in higher education: a metaanalysis comparing peer and teacher marks, *Review of Educational Research*, Vol. 70, No. 3, 287-322
- [2] Nicol, D, Thomson, A, Breslin, C (2014), Rethinking feedback practices in higher education: a peer review perspective, *Assessment & Evaluation in Higher Education*, Vol. 39, No. 1, 102-122
- [3] Thomas, G, Martin, D, Pleasants, K (2021), Using self- and peer-assessment to enhance students' future-learning in higher education, *Journal of University Teaching & Learning Practice*, Vol. 8, No. 1, 52-69
- [4] Chang, D, Hwang, GH, Chang, SC, Wang, SY (2006), Promoting students' cross-disciplinary performance and higher order thinking: a peer assessment-facilitated STEM approach in a mathematics course, *Educational Technology Research and Development*, Vol. 69, 3281-3306
- [5] Chen, YC, Tsai, CC (2009), An educational research course facilitated by online peer assessment, *Innovations in Education and Teaching International*, Vol. 46, No. 1, 105-117
- [6] Cole, JS, Fraser, K (2019), Formative assessment in first-year mathematics through peer review and reflection, Queen's Assessment Hub, Available from: <https://go.qub.ac.uk/assesshub>
- [7] Grant, S (2016), Peer review process completion rates and subsequent student perceptions within completely online versus blended modes of study, *System*, Vol 62, 93-101
- [8] Prichard, RJ, Morrow, D (2017), Comparison of online and face-to-face peer review of writing, *Computers and Composition*, Vol. 46, 87-103
- [9] Knight, L, Steinbach, TA, Adapting peer review to an online course: An exploratory case study, *JITE Research* Vol. 10, No. 1, 81-100