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Engaging with feedback: How do students remediate errors on their weekly quiz

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Maths for Business is a first-year mathematics module for approximately 500 non-mathematics specialists. It has continuous assessment consisting of ten weekly quizzes, worth 40% of the final mark. In 2016/17, students who did not receive the maximum five marks on their weekly quiz were offered the opportunity to resubmit their quiz, with correction(s) and an explanation of their error(s), for one additional mark. We refer to this process as ‘remediation’. In this paper, we examine how students remediate their errors in order to identify features of a ‘good’ remediation. These features are identification, description, and correction of errors. By analysing a subset of students ($n=31$), we observe that a student’s quiz mark, and the cognitive level of the quiz question may impact the nature of the remediation provided.

Keywords: assessment practices in university mathematics education, feedback, remediation of errors, students’ practices at university level.

INTRODUCTION

Maths for Business is a core first-year mathematics module for non-mathematics specialists enrolled on three business programmes in University College Dublin, Ireland. Topics from one- and two-variable Calculus are covered in the module and given the cumulative nature of the content, students should (ideally) achieve the learning outcomes for a topic before proceeding to the next. To encourage mastery of learning outcomes, the module has a continuous assessment component consisting of ten weekly quizzes, worth 40% of the final mark. A week after sitting a quiz, graded quizzes are returned to students with a mark out of five, and tutors provide oral feedback to each tutorial group highlighting the most common errors made. In addition, the lecturer provides an online video entitled “Most Common Errors” and posts a pdf of the quiz solutions online. With our focus on mastery, we believe that students who do not get full marks on a quiz should engage with the feedback to identify and remediate their errors in a timely manner. However, Gibbs and Simpson (2004) discuss how, even if timely and good quality feedback is provided to students, there is no guarantee they will engage with it. Therefore, to encourage this engagement, in 2016/17 we offered students who did not receive full marks on a quiz, one extra mark if they resubmitted their graded quiz one week after it was returned with error(s) identified and corrected. We refer to this process as “remediation”.

Handley, Price and Millar (2011) propose a shift from examining feedback evaluation and attributes to investigating the process of students' engagement with feedback. To this end, we first wanted to explore: which students were most likely to participate in the remediation process; which feedback resources were they most likely to access; and, whether engagement in the process impacted academic achievement in the module. The analysis and findings from this part of the study are described in detail in Howard, Meehan and Parnell (under review). The main findings were that 70% of students who had the opportunity to remediate did so; the most accessed feedback resource was the pdf of the quiz solutions which were made available online; and, students who achieved an average quiz mark of 3-4 (excluding remediation marks) *and* who consistently engaged in the remediation process, exhibited the most learning gains as measured by their performance on the final examination. Secondly, we wanted to examine *how* students remediated quizzes in order to identify aspects of a "good" remediation, and from these findings, refine the instructions given to students at the start of the module on how to remediate their quizzes. We also want to identify and explore what factors might influence the nature of students' remediations. It is this second part of the study that we wish to focus on in this paper by addressing the following research questions:

1. What ways, in general, do students remediate their weekly quizzes?
2. What instructions would we give to future students to assist them in remediating their quizzes?
3. What factors may influence the nature of a student's remediation?

LITERATURE REVIEW

Assessment and feedback

There have been a number of in-depth reviews in the area of assessment and feedback (Bennett, 2011; Sadler, 1989) with some focusing specifically on higher education (Evans, 2013). Assessment is generally discussed under the headings of *formative assessment*, where the primary objective is to provide feedback to the student and evaluation of students' knowledge is secondary; and *summative assessment*, where the primary role is to evaluate students' knowledge and feedback is secondary. Ramaprasad (1983, p. 4) describes feedback as "information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way". Building on this description of feedback in terms of its effect rather than its content, Sadler (1989) argues that the learner must:

- (a) possess a concept of the *standard* (or goal of reference level) being aimed for,
- (b) compare the *actual* (or current) *level of performance* with the standard,
- and (c) engage in appropriate *action* which leads to some closure of the gap (p. 121, italics in original).

While most of the major studies on assessment and feedback relate generally to a variety of subjects, there have been calls for specific domain-focused research (Bennett, 2011). Specifically, in mathematics education at the university level the area of assessment and feedback seems to be under-researched. Of those studies conducted in this area, an emphasis on summative assessment and closed-book examinations has been noted (Iannone & Simpson, 2011; Iannone & Simpson, 2012; Trenholm, Alcock & Robinson, 2015). Underpinning the need to conduct discipline specific research in this area, Iannone and Simpson (2013) found that in contrast to the general literature on assessment, mathematics students prefer traditional closed-book examinations to more alternative assessment methods.

Engagement with feedback

There has been recognition that despite timely and informative feedback being provided to students, students may not take action on it (Gibbs & Simpson, 2004; Handley et al., 2011). Handley et al. (2011) emphasise the difference between the student who skims and bins the feedback to one who takes “responsibility for understanding, interpreting and applying assessment feedback” (p. 557). Price, Handley and Millar (2011) discuss how a student may reject feedback “due to lack of understanding, or based on identity or self-efficacy issues” (p. 892). They further state that students may need more support in taking action on feedback. Of course, feedback needs to be of an appropriate level to help the student. Similar to the remediation process, Covic and Jones (2008) provided psychology students with the opportunity to remediate corrected essay assignments. In this voluntary remediation, 48% of students opted to remediate for potentially higher marks. Students’ feedback consisted of individual and group feedback on their corrected essays as well as an initial grade. We have been unable to find an equivalent study in a mathematics context.

MODULE CONTEXT AND DATA COLLECTION

For our analysis, we only considered students who were completing *Maths for Business* for the first time and who sat the final examination in the module (n=470). In *Maths for Business*, students have the choice of completing the module through using online videos or by attending lectures or a combination of both (Howard, Meehan & Parnell, 2017). The students are assigned to one of two lecture cohort groups and have three lectures weekly. The lectures are designed to be partly interactive with at least 15 minutes for in-class tasks. All students have access to 67 videos/screencasts which cover the entire module content and have an average length of 7 minutes each. These videos were designed and developed by one of the two module lecturers (and third author of the paper). There are no recommended textbooks for this module. Students also have access to the Maths Support Centre, and prior research has shown that students focus on using module resources with very little if any use of external resources such as websites. A student’s final mark on

the module consists of 40% continuous assessment and 60% for the final examination. To encourage consistent engagement with the module and mastery of learning outcomes, *Maths for Business* has ten fifteen-minute weekly quizzes, with each quiz usually consisting of two parts. Each quiz accounts for 5% of the final mark, directly relates to the module's content for the prior week, and is marked out of five. However, only students' best eight quizzes contribute towards their continuous assessment mark of 40%.

One week after completion of a quiz, tutors returned the graded quiz to each student with a mark for both parts of the quiz and the overall mark provided. Tutors also provided oral feedback to their tutorial class on the most common errors made in the quiz. There were approximately 50 students registered for each tutorial. On the university's Virtual Learning Environment (VLE) *Blackboard*, the lecturer provided a video entitled "Most Common Errors" and a pdf copy of the quiz solutions that also indicated the most relevant online videos from the module that a student may wish to revise. In Semester 1 of 2016/17, students who did not receive the full five marks on their quiz were given the opportunity to resubmit their remediated quizzes for one additional mark. The following instructions were provided by the lecturer to students:

- When your quiz is returned to you go over it and identify your errors. Write a sentence beside each error on the quiz sheet so that when you are revising the material again, you will have a note to yourself about where you went wrong.
- If it is the case that your errors were more than just a "slip", then you should write out the correct solution on the quiz sheet and write a sentence or two beside the solution summarising the method.
- You should use a different colour pen so that the tutor can clearly distinguish between what you wrote in the quiz and your remediation comments.
- Imagine you are correcting your friend's quiz and you are explaining to your friend where he/she went wrong.

The third author had difficulty in articulating these instructions, hence the second research question. To remediate a quiz, students were encouraged to use any of the resources available: "Most Common Errors" video; quiz solutions; relevant online videos; Maths Support Centre; tutor feedback; and, friends. From the VLE, we were able to record when a student accessed the first three resources listed, and from Maths Support Centre records we had information on who attended the centre for remediation purposes. We have no data for the number of students who sought help from their friends, or those who made use of the tutor's feedback comments.

Owing to the semester timetable, students could only remediate the first eight quizzes. In total 1,746 remediation marks were awarded. We collected the

remediated quizzes, however, as some from the first quiz are missing, we only use remediated quizzes two to eight inclusive in our qualitative analysis (n=1,511).

QUALITATIVE METHODOLOGY

Qualitative analysis of the remediated quizzes loosely followed the stages of thematic analysis (Braun & Clarke, 2006). Initially, the first author examined the remediated quizzes several times in order to familiarise himself with the data. The remediated quizzes where students *only* provided a full, complete solution as remediation were removed as limited information could be obtained from examining them, especially since complete solutions were available as an online resource. This left 687 remediated quizzes where students had done something other than provide *only* a full solution. Guided by the instructions provided to students, the first author analysed each of the remaining 687 quizzes in order to determine:

1. Has the student successfully identified each error?
2. Has the student provided a solution for each error?
3. Has the student explained their error, and if so, how?

Most quizzes consisted of two questions, therefore each question was analysed separately. In order to ascertain whether a student had identified each of their errors, the first author identified each error on a student's quiz, and noted how many of these the student identified. In terms of examining whether the student had provided a solution for each error, two approaches taken by students were identified. Some students provided a full solution to the complete question even if the error made only related to part of it, whereas other students only wrote a solution for the specific error made. Finally, the first author analysed if, and how, students explained the errors made. Students seemed to vary in their approaches based on variables such as the nature of the question asked, for example procedural or conceptual, and the quiz mark received. We will elaborate on this further in the section below.

RESULTS

To allow for comparison between students with similar levels of achievement on the quizzes, we divided students into four groups based on their average continuous assessment mark (excluding remediation marks) received for the first eight quizzes (4-5, 3-4, 2-3 and 0-2). These groups were of sizes 103, 188, 115 and 64 respectively. Of the 470 students, 47% were female. The following findings are detailed in Howard et al. (under review): students who scored less than two on a quiz were less likely to remediate; students in the two lower groups showed a limited increase in final examination mark as a result of participating in the remediation process in comparison to their peers; and, students who averaged 3-4 on their continuous assessment, particularly benefited from participating in the remediation.

Students' approaches to remediation

After coding was completed on all remediated quizzes, it was possible to compare students' remediation styles within a single quiz as well as the individual progression through all submitted remediations. With regard to error identification, there was a notable difference between students with high and low quiz marks. For students with marks of 3 or 4 in a quiz, mistakes were usually simple calculation slips and thus many students had only one or two errors to identify. This resulted in the majority of students with these marks successfully identifying all their errors. However, for those with lower marks, there were more conceptual misunderstandings to identify as well as several calculation errors. It is not surprising that these students were less successful at identifying every error. For students who received low grades on average, this pattern was clearly evident, but in addition, higher grade students exhibited this style on quizzes where they obtained a lower mark. There was a clear contrast in the level of error identification between an individual students' highest and lowest scoring quiz. This supports our hypothesis that when students achieve low marks, they are less successful at identifying their errors. In terms of provision of solutions to errors, as noted above students either provided a complete solution to the question even if the error only related to part of the solution, or they provided a solution that related to a specific error.

In relation to how students explained their errors, three codes or types of explanations were identified. Based on our knowledge of feedback, we define these explanations as: diagnostic, instructional, and objective. Some students explained errors in the context of incorrect notions or ideas that lead to them making a mistake. We refer to this approach as being diagnostic for example, "I thought brackets implied find the product but I should have used the chain rule". Others focused on providing advice or helpful tips to themselves to help prevent mistakes in any similar questions they faced in future. We refer to this approach as instructional for example, "Add powers together as they have the same base (multiply rule). Finally take away the powers from each other (division/fraction rule)". The final, and most common approach, was an objective explanation of the error, simply describing the specific error without referring to prior knowledge or providing instructions on how they might answer future questions on the topic for example, "I compounded continuously but the question asked for quarterly".

Additionally, there was a less frequent code for whether a student provided an incorrect statement, or identified their errors incorrectly. Having addressed the first research question, we propose that in future the following instructions be given to students:

1. With a different coloured pen to the one in which the quiz was completed, put an "X" beside each error or, where relevant, indicate an omission in your work.

2. Provide an explanation for each of your errors, either describing the error or if you can, elaborate on any incorrect notions you had which may have led to the error.
3. Correct each of your errors by writing the correct version beside each one. Avoid copying down the written solutions for each quiz without explicitly consulting your areas of error.
4. If you are still unsure how to remediate your quiz or need help with the questions, we suggest you visit the Maths Support Centre for help.

In addition to the above instructions, we would provide students with exemplars of “good” remediations.

In-depth analysis of specific students’ remediations

We now turn to Research Question 3: What factors may influence the nature of a student’s remediation? Owing to the large amount of data involved, we have chosen to address this research question by examining a specific subset of the data. It is our hope that this analysis will help us identify factors that may prove beneficial when analysing the larger data set. We consider a subset of students ($n=31$) who remediated at least six quizzes and achieved on average 3-4 quiz marks as these had particularly benefitted from the remediation (Howard, et al., under review) and we could investigate their style of remediating over several quizzes. These students attended between 1-26 lectures and accessed between 11-232 videos with students from the weaker mathematical backgrounds (based on the Irish State Examination Mathematics results) accessing more resources than the others. All of these students passed the end-of-semester examination achieving at least a B grade (60%) and 58% were female. Twelve students accessed the Maths Support Centre and all but one of these were female. Detailed records from centre show that at least five of these students received help from the tutors on remediating the quizzes, including quizzes where they received four out of five marks. Seeking help from the Maths Support Centre for remediating the quizzes was uncommon among the larger *Maths for Business* cohort. Overall, based on their module resource usage, these students seem to work consistently throughout the semester.

To investigate how these 31 students remediated, their coded, remediated quizzes were further analysed to examine any prevalent styles of remediation. Within this group some students remediated consistently in the same manner each week, while others exhibited various remediation styles. Due to the initial division made between students writing only a full solution as remediation, and those who articulated some form of further explanation, we decided to categorise a student’s overall remediation style based on the amount of times a remediation consisting of just a solution was submitted. Students could be split into roughly equal groups based on whether they provided only full solution in every remediated quiz ($n=10$), more than half of their

remediated quizzes (n=8) or in half or less of their remediated quizzes (n=13). Overall there was no obvious difference in the resources accessed (Maths Support Centre, quiz solutions etc.) between the three groups of students. In terms of error identification, these students were, in general, successful in identifying all their errors. A prevalent remediation style consisted of students identifying their errors, providing an objective explanation of the error, and writing a solution of the specific error. With regard to the three main approaches to error explanation, the objective explanation was the most common method. Interestingly, the diagnostic and instructional approaches were rarely used consistently in remediations by individual students.

The nature of the quiz question seemed to impact the remediation approach. The quiz questions could be considered under the headings: conceptual ('The following is a graph of the first derivative $f'(x)$ of a function $f(x)$. Your friend is attempting this problem...He asks you: "How can you tell that f has a minimum at $x=2$ just by looking at the graph?'), procedural ('Find all first and second-order partial derivatives of $z = f(x,y) = \dots$) and economic context ('Compute price elasticity of demand, $E\dots$ In one sentence, explain what your answer means'). Notably, for these students, quiz questions that were more conceptual in nature, resulted in more "solution only" remediations. As full solutions were provided as a resource to students, it was possible to copy them and submit it as remediation. Thus, an increase in the number of solution-only remediations for a given quiz question may allude to a lack of student understanding of the module content. A number of quiz questions also resulted in more diagnostic remediation responses. These questions were more application based, and focused on application of techniques to economic contexts. The two quizzes that contained these applied questions had the highest average marks of all eight quizzes, with 21/31 quizzes obtaining full marks between the two. We believe the increased use of diagnostic remediations may indicate students find it easier to locate misconceptions in mathematical application than with more abstract questions.

DISCUSSION AND CONCLUSION

Semester 1 2016/17 was the first time we implemented the remediation process. Following from the definitions of Ramaprasad (1983) and Sadler (1989), students were provided with their actual level of understanding (mark out of five), the desired level of understanding (for example, pdf of quiz solutions), and were incentivised to engage with feedback for the intention of closing the feedback gap. Gibbs and Simpson (2004) propose that even if feedback is provided, students will not necessarily use it. Despite assessment marks being provided as an incentive, on average 70% of students engaged in the remediation process. Initially, we considered providing remediation marks on a sliding scale based on a student's initial quiz mark received. This method would reflect the additional work of remediating for lower-

scoring students and offer them additional incentive over high-scoring students, however, this system was not implemented as it required additional time and effort from the tutors.

Qualitative analysis of the entire set of remediated quizzes allowed for the isolation of certain properties that indicate whether a student is engaging with their assessment feedback. We note that a substantial number of students provided the full solution only for their remediation, however we advocate the three-step approach - identifying, explaining and correcting errors encourages students to recognise their own standard and utilise feedback to help close the gap between their own level and the desired standard. It is for this reason that we suggest this style as a guideline for future processes similar to remediation.

Owing to the brevity of the explanations provided in this paper on the different remediation responses, it is pertinent to mention different avenues that will be investigated as this research progresses. The in-depth analysis of the 31 students in this paper suggests that task design and a student's initial grade influences remediation style. Different task types elicited different remediation responses, based on whether the question was conceptually or application based. Perhaps, owing to a lack of understanding of the content material or the inability to transfer knowledge from one context to another, students tended to provide full solutions to conceptual questions. In addition, quizzes where students received lower grades tended to result in more solution only remediations. As these solutions are available as resources, this may suggest that some students utilise solutions when they are unable to fully identify and understand their errors on a quiz. From this, one can hypothesise that the remediation process may have less benefit to weaker students as a level of baseline knowledge may be required in order to engage with the process. In subsequent research, task design and initial quiz mark will be examined further to discern any influence on remediation response across the full set of remediated quizzes.

One limitation of our study is the lack of student perspective on the remediation process. Also, while the remediation process was beneficial to the students of this large non-specialist mathematics module, an investigation of the benefits/drawbacks of the remediation process for mathematics modules for specialists would be a constructive contrast with this research.

This study was completed with approval from the University College Dublin ethics committee in accordance with ethics applications LS-E-17-20-Copeland-Meehan and LS-16-48-Howard-Meehan.

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