STUDENT-LECTURER PARTNERSHIPS IN UNDERGRADUATE MATHEMATICS QUESTION DESIGN

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ABSTRACT

Our exploratory study examines the benefits of student-lecturer partnerships in course design at a university level. This project is situated within a larger design research project investigating a blended learning intervention in a stage II service mathematics course. A mathematics *Lecturer* and a *Student* entering postgraduate mathematics study both independently composed questions for online pre-lecture quizzes related to the calculus section of the course. Utilising Schoenfeld's (2010) theory of goal-oriented decision making, we unpack the complexity of the design process by examining the three fundamental factors: Resources, Orientations and Goals (R/O/G). Using this theoretical lens, we interpret the results of the study by accounting for the differences between the *Lecturer*'s and the *Student*'s quiz questions through an analysis of their R/O/Gs. Our findings suggest that interpreting the differences in question construction provides insight into student learning of mathematics from both student and lecturer perspectives as well as how students engage with blended learning resources. The systematic approach that we describe, utilising the R/O/G framework for an analysis of the design process, can be used for developing and refining the assessment by other student-lecturer partnerships in other educational settings.

INTRODUCTION

'We know what we are, but know not what we may be.'
– William Shakespeare

Opportunities for teaching innovations and technological advancements are rapidly changing how university mathematics courses are taught. Handouts become slides. Assessments are submitted virtually. Calculations become code. All while new ways of assessing students' learning of mathematics are continuously being developed. In this new age, there are advantages to students and lecturers becoming both educators and learners.

Our project involved a second-year general mathematics course *Lecturer* inviting a *Student* to write questions for the course. The project aimed to explore the types of questions deemed conducive to the learning of mathematics by a teacher compared to a student. An important feature of the setting for this explorative study is a blended learning environment. Blended learning, the integration of face-to-face and online instruction, is now widely adopted as the 'new normal' in course delivery across tertiary institutions. In mathematics classes, this new modality of instruction is commonly seen at all levels, yet the extent to which it is effective raises important questions about its pedagogical merit and the responsibility of instructors with its evaluation (for reviews, see Borba, Askar, Engelbrecht, Gadanidis, Llinares, & Aguilar, 2016).

Background setting

In our study, the *Lecturer* comes from a pure mathematics background and has been lecturing both undergraduate and postgraduate university courses for twelve years. She was a part of a blended learning initiative for a second-year course at the University of Auckland and began including short online quizzes between lectures in 2016 (Evans, Kensington-Miller, & Novak, 2019).

The quizzes are worth 7% of the final grade and require the students to answer two multiple-choice questions online before the next lecture, assessing the content of the previous lecture. The students are allowed two attempts at completing each quiz and their highest score is recorded. Each question is randomly selected from a bank of questions containing 2-3 versions (for example, different numerical values). The time limit is set for 30 minutes to provide enough time for students to revise the material while taking each quiz.

The impact of the incorporation of quizzes into this course was previously researched and reported. The findings suggest that this relatively small change in course instruction can improve efficiency and effectiveness of educational exchange. Researchers analysed data from multiple sources and provided evidence that this intervention resulted in a sustained increase in frequency of students' engagement with mathematics, increased attendance of lectures and improved grades (Evans, Kensington-Miller, & Novak, 2019). Our study was designed in this setting, taking into account and building on the findings from the previous research.

The *Student* involved in the project was entering postgraduate study in Mathematics with a focus in Mathematics Education after completing an undergraduate degree majoring in Pure Mathematics and English. She had taken the course herself with a different lecturer, but prior to the incorporation of blended learning and quizzes.

Theoretical background

A theoretical concept relevant to our research is the notion of partnership between the *Student* and the *Lecturer*. In the UK Higher Education Academy's framework for partnership in learning and teaching in higher education, it is stated that in these partnerships, 'staff experience renewed engagement with and transformed thinking about their practice, and a deeper understanding of contributions to an academic community' (HEA, 2014, p. 2). Involving tertiary students in the instructional design is well established in higher education but often comes with challenges and concerns for both the academic staff and students (Money, Dinning, Nixon, Walsh, & Magill, 2016). Some recent research has been carried out and provided insights into successful practices in forming student partnerships in tertiary education (Healey, Flint, & Harrington, 2014), but it has not been specific to mathematics.

The Catalyst Project (Jaworski, Treffert-Thomas, & Hewitt, 2018) at Loughborough University is a recent research endeavour related to exploring the process and results of partnerships between mathematics students and educators. The university runs a one-year course for Foundation Students (FSs) who do not hold the correct qualifications to start the degree they are intending. Student Partners (SPs), who were former FSs, partnered with lecturers to design computer-based tasks for FSs. The team investigated how their SPs engaged with designing the tasks and how the FSs interacted with the task. The analysis of The Catalyst Project is still in its early stages but is providing valuable insight into how FSs learn and may prove beneficial to the SPs. Our project, like The Catalyst Project, explores the partnership between educators and learners but differs in its design, data collection, research questions, and overall aims.

We examine the differences in the quiz questions written by the *Lecturer* and the *Student* utilising the theory of decision-making developed by Alan Schoenfeld in ‘How We Think’ (Schoenfeld, 2010). According to this theory, an inspection of a teacher’s decision-making process during a teaching-learning interaction can be conducted through the examination of three fundamental factors:

- Teacher *Resources*—primarily knowledge, but also including classroom resources such as technological gadgets (tablets, mobile phones, clickers, etc.);
- Teacher *Orientations* to the domain—in essence, what they consider important which is shaped by their beliefs and attitudes towards mathematics;
- Teacher *Goals* for the teaching interaction—in essence, what they are trying to achieve in a particular teaching-learning event (Schoenfeld, Thomas, & Barton, 2016).

There is previous research done at the University of Auckland in using Schoenfeld’s (2010) theory of decision-making as a tool for lecturers’ professional development (Oates & Evans, 2017; Paterson & Evans, 2013; Schoenfeld et al., 2016). One of the research questions from Schoenfeld et al. (2016) was, ‘How can Schoenfeld’s resources, orientation and goals (R/O/G) framework be adapted to support lecturer professional development?’ Participating lecturers were asked to engage with their R/O/Gs. These were then reflected on in relation to a short video excerpt from a lecture and used to catalyse discussion around lecturer in-the-moment teaching decisions. They concluded that the adapted R/O/G framework was effective in stimulating and centering their discussions.

We extend on this application of the R/O/G framework by having the *Student* and the *Lecturer* maintain an active awareness of their R/O/Gs during the construction of their questions. Using this theoretical lens, we interpret the results of the study by accounting for these differences through an analysis of their R/O/Gs. We hypothesised that gaining insight into student R/O/Gs (student perspectives) can be beneficial to the lecturer in course development.

Our main research questions were:

- How can analysing questions devised by a student for assessing learning in a course compared with questions devised by a lecturer support the development of courses featuring blended learning?
- How can Schoenfeld’s R/O/G framework be used to account for perceived differences between what a student finds valuable to student learning and what a lecturer finds valuable to student learning in a course featuring blended learning?

METHOD

Methodological framework

This research was conducted as part of a larger design research project investigating the impact of online quizzes between lectures in a university mathematics course. Design research differs from traditional experimental research designs in that initial concepts for learning are constructed but may be adjusted during the testing process. In education, conducting purely experimental research often results in an inability to generalize, as natural learning environments contain numerous variables that are impossible to replicate exactly. Design research aims to advise, ‘namely to give theoretical insights into how particular ways of teaching and learning can be promoted’ (Bakker, 2018, p. 8) through interactive and iterative cycles of development and research, as characterized in Figure 1 (adapted from Goodchild, 2014).

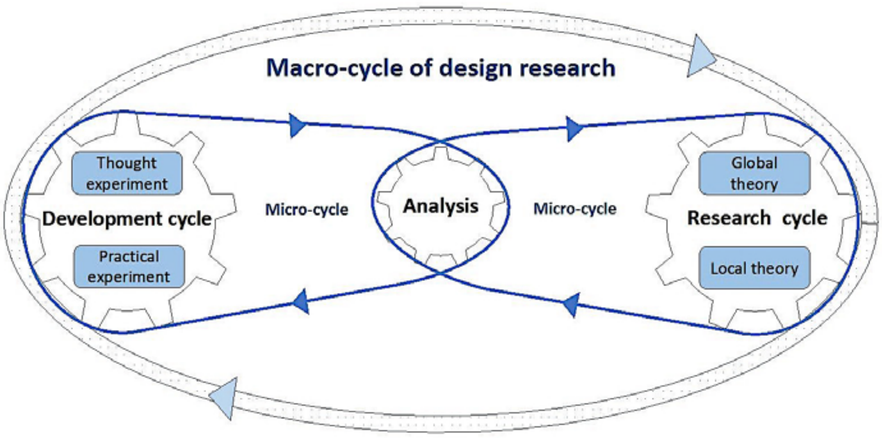

Figure 1: Design research: Cogwheels in motion, chain-driven by design principles

As mentioned in the introduction, the first macro-cycle of the design research project was completed during 2016-2018 with results reported in Evans et al. (2019). This project represents a *Research micro-cycle* (see Fig. 1 on the right) of this larger design research project, building on the findings from the first macro-cycle. The findings from this *Research micro-cycle* are used to inform future *Development* and *Research* cycles of the project. The knowledge yielded by design research is commonly summarized as design principles, which change and develop through the cycles. Design principles are typically summarized in the following form.

- If you want to design intervention X [for purpose/function Y in context Z]
- then you are best advised to give that intervention the characteristics C_1, C_2,…, C_m [substantive emphasis]
- and to do that via procedures P_1, P_2, …, P_n [methodological emphasis]
- because of theoretical arguments T_1, T_2,…, T_p
- and empirical arguments E_1, E_2,…, E_q (Van den Akker, 2013, p. 67)

We will offer the design principle that resulted from this study in our findings.

Study setting

As part of a summer research project, the *Lecturer* assigned the *Student* to research literature that discusses the use of Schoenfeld's R/O/G framework in mathematics education research. The *Student* then wrote two multiple-choice questions for each of the ten lecture topics in the Calculus section of the course. If the questions were found to be valuable, then they would be included in future online quizzes for the course. An important difference of method between our research and that of The Catalyst Project (Jaworski et al., 2018) is the blinded process we engaged in developing the questions in contrast to the gradual collaborative process where SPs were given feedback as they progressed. The only instruction given to the *Student* was to consider the R/O/G framework when writing the questions in order to analyse the decision-making process later. The *Lecturer* and the *Student* did not share their R/O/Gs with each other and did not discuss the content of the course, with the intention of avoiding an influence on the question design process. The *Student* was provided with access to all the course materials with the exception of previous quizzes.

The *Lecturer*'s questions in this analysis were used in the second semester of 2017 in Mathematics XXXX course – a large service stage II course with 450 students enrolled. She described her method of writing questions to be quick and direct. She comments, 'I was true to my R/O/G the whole way – just two main learning outcomes from the previous lecture only.'

The *Student* wrote the questions over a period of five weeks and was in a position to spend significant time thinking about the types of questions she wanted to ask, as well as research, draft, and review them. She kept detailed notes on how each question related to her R/O/G. Once completed, the *Lecturer* and the *Student* came together to compare their quizzes and consider the resulting implications, with their R/O/Gs as a foundation for discussion.

QUESTIONS OVERVIEW

The questions written by the *Lecturer* were similar to the questions in the coursebook, with a primary focus on students successfully reproducing the method taught in class. In practice, these questions had a very high success rate for students, with the large majority answering correctly and well within the 30-minute time limit. The three fundamental types of questions asked by the *Lecturer* aimed for students to:

- practice the method;
- recall definitions with correct mathematical notation;
- recall theorems/claims.

Three types of questions emerged for the *Student*. These can be distinguished through the goals for students in the course to:

- practice the method;
- build intuition and understanding through the use of visualisation;
- build intuition and understanding through the use of non-examples.

Below we compare questions on the same topic and share noteworthy examples.

Let $f(x,y) = 6xy - x^6 - y^6$. How many relative minima points does the function f have?

- 0
- 1
- 2
- 3

Figure 2: Lecturer-written question on optimisation

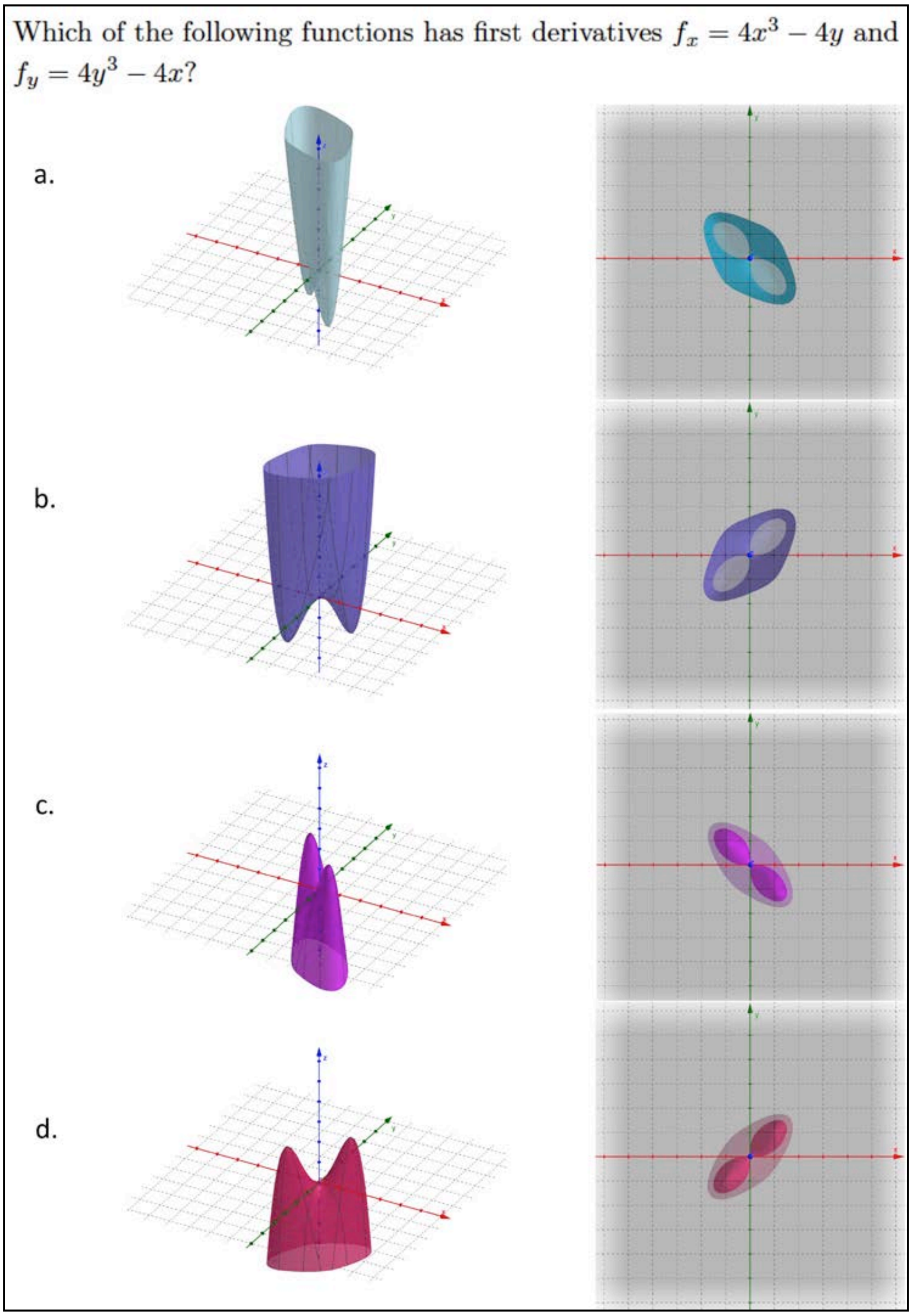

Figure 3: Student-written question on optimisation

Both questions on optimisation (Figures 2 and 3) have the intention of getting students to identify critical points, though the *Student*'s question is not as transparent. The *Student* comments, 'This question extends the student thinking from simply reproducing a method. Visualising assists in their understanding of the concept and helps create connections in the mathematics.' The *Student* explores using visual representations in several questions, while the *Lecturer* does not use any visuals. The *Lecturer* comments:

> The reason I did not use any visuals is because, coming from pure maths background, neither have I possessed sufficient technological capability, nor had previous

experience in the use of technological resources that could be easily incorporated into our new Learning Management System (Canvas), which was rolled out at the University in early 2016, when I first wrote the questions. After I wrote them, other requirements of my busy academic life took over, so it was never a priority to revisit the quizzes or upskill myself and find out about new resources available for integration with Canvas.

The lack of time and incentives to develop familiarity with technologs of teaching and learning. Lecturers' background and their academic environment shape their R/O/Gs in a profound way. We present the detailed analysis of the data through the R/O/G lens in the next section.

The Squeezing Theorem:
Given a sequence $\{a_n\}_{n=1}^{\infty}$, suppose that there exist two other sequences $\{b_n\}_{n=1}^{\infty}$ and $\{c_n\}_{n=1}^{\infty}$ such that $b_n \leq a_n \leq c_n$ for all $n \geq n_0$ (where $n_o \in \mathbb{N}$).

Which one of the following conditions implies $\lim_{n\to\infty} a_n$ exists?

- $\lim_{n\to\infty} b_n = \lim_{n\to\infty} c_n$
- $\lim_{n\to\infty}(b_n + c_n) = \lim_{n\to\infty} b_n + \lim_{n\to\infty} c_n$
- $|b_n| \leq L$ and $|c_n| \leq L$ for all $n \in \mathbb{N}$
- $-L \leq a_n \leq L$ for all $n \in \mathbb{N}$

Figure 4: Lecturer-written question on the Squeezing Theorem

Which one of the following does NOT correctly depict an application of the Squeezing Theorem in finding a limit?

a.

$\frac{-2}{n^2} + 2 \leq \frac{\sin n + \cos n}{n^2} + 2 \leq \frac{2}{n^2} + 2$

b.

$\frac{-1}{n+1} \leq \frac{\cos(n^2)}{n+1} \leq \frac{1}{n+1}$

c.

$-(n+1) \leq \frac{n+1}{\cos n} \leq n+1$

d.

$\frac{-2}{n^2} \leq \frac{\sin n + \cos n}{n^2} \leq \frac{2}{n^2}$

Figure 5: Student-written question on the Squeezing Theorem

Figures 4 and 5 comprise essentially the same question. The *Lecturer*'s question demands a recognition of the mathematical notation and a recall of the statement of the Squeezing Theorem, while the *Student*'s question checks if they understand what the notation means and focuses their attention on an incorrect application of the Squeezing Theorem – a non-example of a sort. While both are crucial to student progression in the course, the formal definition can be found easily both in the coursebook and online. The *Student* included no questions asking the class to reproduce the statement of the theorem. We can see a similar pattern in Figures 6 and 7. The *Student* again takes into account what information is immediately available to the students taking the quizzes.

Which one of the following is the Taylor polynomial of degree k for $f(x)$ about the point c?

- $p_k(x) = f(c) + f'(c)(x-c) + \frac{f^{(2)}(c)(x-c)^2}{2!} + \ldots + \frac{f^{(k)}(c)(x-c)^k}{k!}$
- $p_k(x) = f(c) + f'(c)(x-c) + \frac{f^{(2)}(c)(x-c)}{2!} + \ldots + \frac{f^{(k)}(c)(x-c)^k}{k!}$
- $p_k(x) = f(x) + f'(x)(x-c) + \frac{f^{(2)}(x)(x-c)^2}{2!} + \ldots + \frac{f^{(k)}(x)(x-c)^k}{k!}$
- $p_k(x) = f(x) + f'(c)(x-c) + \frac{f^{(2)}(c)(x-c)^2}{2!} + \ldots + \frac{f^{(k-1)}(c)(x-c)^{k-1}}{(k-1)!}$

Figure 6: Lecturer-written question on Taylor polynomials/Taylor series

Which one of the following combinations of statements is true?

a. A Taylor series is a representation of a function as an infinite sum of terms, which is used to approximate the value of the function.

   Lower degree Taylor polynomials provide better approximation about a centre.

   Inside the domain of the Interval of Convergence, the Taylor series is an unsuitable approximation to the function.

b. A Taylor series is a represenation of a function as an infnite sum of terms, which is used to approximate the value of other functions.

   Lower degree Taylor polynomials provide better approximation about a centre.

   Inside the domain of the Interval of Convergence, the Taylor series is an unsuitable approximation to the function.

c. A Taylor series is a polynomial used to approximate only other polynomials.

   Higher degree Taylor polynomials provide better approximation about a centre.

   Outside the domain of the Interval of Convergence, the Taylor series is an unsuitable approximation to the function.

d. A Taylor series is a polynomial used to approximate only other functions.

   Higher degree Taylor polynomials provide better approximation about a centre.

   Outside the domain of the Interval of Convergence, the Taylor series is an unsuitable approximation to the function.

Figure 7: Student-written question on Taylor polynomials/Taylor series

The *Student* frequently employed 'combination of statements' questions (as seen in Figure 7), which focused on either interpreting the mathematics in more colloquial terms outside the standard definition or extending student thinking by drawing attention to non-examples. The *Student* felt this style of question prevented easily looking up solutions online and required thinking about the language of mathematics.

Similar intent – to prevent students from looking up solutions online – is observed in the questions that demanded an application of a method. In her notes for the question in Figure 8, the *Student* states, 'avoiding just googling the solution through splitting the question into parts without final solution.' In contrast, the *Lecturer*'s questions on integration all had the form with solutions for the final integral.

Correctly select the *parts* and the integration by parts equation to $\int \frac{\ln(3x)}{x^8}dx$.

a.

$u = \ln(3x) \qquad du = \frac{1}{x}dx$

$v = -\frac{1}{7x^7} \qquad dv = \frac{1}{x^8}dx$

$\int \frac{\ln(3x)}{x^8}dx = -\ln(3x)\frac{1}{7x^7} + \int \frac{1}{7x^7}\frac{1}{x}dx$

b.

$u = \ln(3x) \qquad du = \frac{1}{x}dx$

$v = \frac{1}{7x^7} \qquad dv = \frac{1}{x^8}dx$

$\int \frac{\ln(3x)}{x^8}dx = -\ln(3x)\frac{1}{7x^7} - \int \frac{1}{7x^7}\frac{1}{x}dx$

c.

$u = \ln(3x) \qquad du = \frac{1}{3x}dx$

$v = \frac{1}{x^8} \qquad dv = \frac{1}{7x^7}dx$

$\int \frac{\ln(3x)}{x^8}dx = \ln(3x)\frac{1}{x^8} - \int \frac{1}{x^8}\frac{1}{3x}dx$

d.

$u = \frac{1}{x^8} \qquad du = -\frac{8}{x^7}dx$

$v = \ln(3x) \qquad dv = \frac{1}{x}dx$

$\int \frac{\ln(3x)}{x^8}dx = \ln(3x)\frac{1}{x^8} - \int \ln(3x)\left(-\frac{8}{x^7}\right)dx$

Figure 8: Student-written question on the integration by parts

Another distinction to be noted is that the *Lecturer* included questions with real-world contexts (e.g. Figure 9) where the student included none. The *Student* revealed she felt real-world questions served little purpose in understanding the mathematics itself and were unnecessarily time-consuming for students in the context of these quizzes.

A mobile-phone manufacturer produces two types of phones: standard and premium. Weekly production is represented by x units of standard phones and y units of premium phones. Weekly revenue is $100xy$, and costs are $x^2 + y^2$. It follows the weekly profit is given by the function $f(x, y) = 100xy - x^2 - y^2$. Unfortunately there is a plant constraint requiring: $x^5 + y^5 = 300$. The company's leadership team would like to maximise the profit, but the constraint must be obeyed. Which one of the following systems of equations represents the Lagrange multiplier condition that must be satisfied at a point that maximises the profit?

- $\begin{cases} 100y - 2x = \lambda 5x^4 \\ 100x - 2y = \lambda 5y^4 \\ x^5 + y^5 = 300 \end{cases}$
- $\begin{cases} 100y - 2x = \lambda 5x \\ 100x - 2y = \lambda 5y \\ x^5 + y^5 = 300 \end{cases}$
- $\begin{cases} 100y - 2x = \lambda 5x \\ 100x - 2y = \lambda 5y \end{cases}$
- $\begin{cases} 100y - 2x = \lambda(5x - 300) \\ 100x - 2y = \lambda(5y - 300) \\ x^5 + y^5 = 300 \end{cases}$

Figure 9: Lecturer-written question on Lagrange multipliers

A comparison of the key points that were chosen by the *Student* and the *Lecturer* for each lecture was made. Outlined in Table 1 are examples of the key points identified by the *Lecturer* and the *Student* as targets for assessment by the quizzes for the three lectures in which the distinction was observed.

Table 1: Examples of key points from lectures to be assessed in quizzes as determined by the *Lecturer* and the *Student* – three lectures with the most distinction

Lecture topic	Both	Lecturer	Student
Constrained Optimization	- optimising function with constraints	- interpreting real-world questions	- interpreting through graphical visualisation
Sequences: Introduction		- finding the n^{th} term formula for a sequence - recalling the Squeezing Theorem	- using the Squeezing Theorem correctly (via non-example) - finding limits of sequences/

		establishing convergence
Taylor Series	- recalling Taylor and Maclaurin polynomials formula - finding Taylor and Maclaurin polynomials	- interpreting definitions through the use of non-examples and colloquial terms - establishing convergence of power series

Table 2: Summary of the key points identified by the *Lecturer* and the *Student* from all lectures in the study

	Same key points	Shared one key point	Different key points
Number of quizzes	6	2	2

RESULTS

We can see in Table 2 that the *Lecturer* and the *Student* frequently valued the same main learning outcomes from each lecture. What was more varied was how they addressed assessment of those learning outcomes.

It is plausible that a key difference that emerged lay in the core, not necessarily conscious, belief of what will create a successful student in that course – this core belief determines the Orientations of the *Lecturer* and the *Student*. This, according to Schoenfeld's (2010) theory, in turn, orientate the formation of their Goals. It is important to note that most of the students in the course are not mathematics majors. The course content is skills driven to serve the needs of other majors like finance, economics, physics, computer science, and chemistry. There are also almost no proofs in the course. The *Lecturer*'s questions were in line with the idea that practice and repetition will create a student who can fulfil all of the requirements of the course, and thus, provide the tools needed to satisfy their major. The *Student* took the approach that a depth of intuitive understanding will develop better recall and confidence in the subject.

Explaining the differences through the ROG lens

The primary Resource of both the *Student* and the *Lecturer* was their knowledge of the material. The *Lecturer* had more depth and experience in her mathematical knowledge and knowledge of the course, and the student cohort, while the *Student* had been through the process of learning the content more recently. Essentially, we have the *Lecturer*'s insider knowledge of how a large population of students learn mathematics, and the *Student*'s insider knowledge of how an individual student learns mathematics.

Interestingly, while both the *Student* and the *Lecturer* included course materials under their Resources, the *Student* also explicitly included the Internet. The consequence of this is a key finding of our study. This awareness suggests a greater familiarity with working online and an understanding of the advantages and disadvantages of this in taking mathematics courses. From secondary school to postgraduate study, it is common to find solutions to very similar examples, if not identical assessment questions, on numerous websites. This plethora of mathematical resources can be hugely beneficial to the aspiring mathematician. However, it has the possibility to be detrimental to those students who seek to get through assessments quickly, likely restricting their quality of engagement with the content and not reinforcing their understanding. As the blended learning intervention that was the setting for this study reported a significant improvement in course performance across all students (Evans et al., 2019), it seems probable that most students are not abusing the online and independent nature of the quizzes. However, we can still seek to further improve their design. The *Student* in describing her design process comments, ‘I attempted to write questions (where possible) that are not easily “google-able”’. Concluding the project, she states:

> There are many calculators online that solve everything from series to integration by parts (step by step). I worked around this by breaking down the questions into parts, so the students were forced to understand the nuances of the method...The temptation for free marks is always high, so avoiding this issue is preferable to ensure student understanding.

In their reflective meeting, the *Lecturer* had the epiphany of the significance of generational differences in exploring blended learning. We have discovered that student partnerships can provide vital insight into using different forms of technology effectively as a medium for learning.

The uncovered difference in the core belief of the *Lecturer* and the *Student* regarding how to enable success for students enrolled in this service course explicate the distinction in their Orientations, which, in turn, dictate the formation of their Goals in the design of the quizzes. The *Student* states she wants ‘to develop student intuition and a comprehensive understanding of the mathematics so they make connections and enjoy the mathematics.’ Whereas, the *Lecturer* has obvious concerns about student performance on quizzes as a reflection of the course. This concern, perhaps, has shaped the format of the questions she created to match the examples that are covered in class or provided in the coursebook. The *Student* did not have the same pressure and in composing the questions, sought to promote an appreciation of the mathematics, with significantly less regard for students’ expectations for quiz questions to match worked examples that have been already provided to them.

Assessment can be a double-edged sword in that, if structured correctly, can provide great incentive for student engagement, but can also mean students may prioritise correct answers over understanding if the option is there. The *Student* approached the quizzes as a further learning opportunity with, ultimately, less consideration for the assessed performance of the students taking them.

Aligned with perspective, we recognise the role of the Orientations as a motivator for the varied responses in the Goals:

Lecturer:

- To develop a bank of quizzes that will be delivered on-line preceding every lecture (to increase learners’ frequency of engagement with content)
- To write questions that assess two main learning outcomes from the previous lecture only

Student:

- Write questions that promote ‘aha’ moments in students / Write questions that allow students to discover the relationships within the mathematics they are studying
- Keep students up to date/refreshed with the course content
- Provide an opportunity for students to practice the method

The approaches of teaching how to do mathematics (skills-based) and teaching in-depth comprehension are a well-known struggle in mathematics education. As previously highlighted, most of the students in the course major in other subjects that they are trying to understand deeply and simply need to be able to execute the mathematics. The *Student* was a more recent learner of this level of mathematics and argued that deeply understanding the mathematics leads to more consistent results over time. Simultaneously, the *Lecturer* had insight into the types of students taking this course. In particular, the majority of the students will not be engaging with mathematics at this level again once the course is completed. The effectiveness of the different style of questions can only be gauged by trial, which will take place in a future.

CONCLUSION

Benefit to lecturer development

As a consequence of participation in the study, the *Lecturer* reported a major change in her perspective that will affect her Goals in the future design process. It was triggered by becoming cognisant of the *Student*'s Resources - in particular the Internet. The acute realisation of the significance in generational change brought to the fore the extent of use of freely available online resources by students and, most importantly, students' perception of those 'google-able' resources as being first port of call when answering quiz question. In unpacking the *Student*'s design process, the *Lecturer* paid particular attention to the *Student*'s intent to write non-'Google-able' questions and the tactics employed. Through engaging in this analysis, the *Lecturer* was able to internalise these insights. This has altered her Goals for future design processes to actively work around potentially detrimental consequences of the accessibility of ever-growing technological resources.

Benefit to student development

Similarly to The Catalyst Project (Jaworski et al., 2018), we have reviewed how the student partner engaged with the task. In our project, the *Student* reported that engaging with the content of the course on this level clarified aspects of the content and promoted a deeper understanding of the mathematics. Two features of the process stood out as particularly beneficial. The first was composing the 'combination of statements' questions, as illustrated in Figure 7. She found the process of transitioning the concepts between the mathematical notation and normal language cemented her understanding of the concepts and their corresponding applications. The other helpful characteristic of the process was attempting to predict student errors for the possible solutions. In taking time to consider where mistakes could be made, she now feels she developed skills to anticipate errors in her own mathematics.

We offer the following design principle as a result from our study. If you want to design online quizzes for a service mathematics course with an aim to enhance quality of engagement and learning, then you are advised to consider incorporating features deemed valuable by a student in designing the questions. These could be identified through a *Student* and *Lecturer* independently writing their R/O/Gs (Schoenfeld, 2010), devising questions following those R/O/Gs for the quizzes, and then examining the results through the R/O/G lens. The basis for this case is supported by the theoretical considerations on the advantages of student partnerships and by the conclusions of our exploratory study. In our analysis, we have tested a student's construction of questions for a blended learning assessment in comparison to a lecturer's and found that an adaptation of Schoenfeld's R/O/G framework accounted for the differences and allowed insights into question design.

The direct findings for this course may not prove directly transferable to another course as the usefulness of one student on one topic is limited. However, the resulting design principle is useful and transferable to other educational settings, and we suggest, particularly relevant for courses featuring blended learning. Central to the design is the insights offered by student partnerships in course development. Our analysis yields the benefits of student partnerships in courses incorporating blended learning through student familiarity with modern technological resources in their study. This familiarity can be used to identify and eliminate disadvantages of working online, as well as promote innovative use of the blended learning resources in learning and assessment. It is plausible to suggest that, generally, through understanding the different R/O/Gs of lecturers and students, such collaborations would allow for more assessment conducive to learning at the university level. This project is ongoing and further research will be conducted to explore how the students in the service mathematics course respond and perform to the questions written by the *Student*.

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