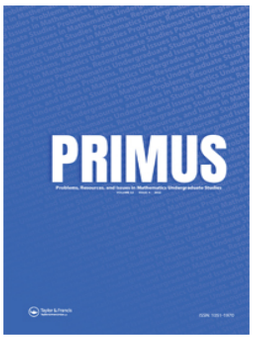

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Changing Students' Perception of Learning Mathematics

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Changing Students' Perception of Learning Mathematics

Sunitha Prabhu

ABSTRACT
Teaching Mathematics to tertiary students can be a challenge to educators, mainly because they must deal with learners' varying levels of readiness. Some of the factors attributing to the variability are learners' perceptions of mathematics, their previous learning experiences, and fear of failure. We implemented a teaching approach to facilitate student ownership through active peer involvement and flexibility with assessments. In this paper, we analyze students' perceptions of learning mathematics when using the new approach for three consecutive semesters. We discuss the results of our study and the factors that helped students overcome their inhibitions and appreciate mathematical concepts.

KEYWORDS
Flexible assessments; flipped classroom; mathematics; peer involvement; student engagement; student ownership

1. INTRODUCTION

Mathematics is essential in many areas of study, especially in computing and engineering. It is unfortunate that many learners perceive mathematics as a difficult subject. Often adults openly express their lack of competency in and dislike of mathematics without hesitation [5]. The reason for the negative attitude towards learning mathematics can be connected to students' previous experiences with learning mathematics; and the general acceptance among students that it is normal, or sometimes even "cool," to dislike mathematics. This generally contributes to learners avoiding mathematics and a feeling of failure to complete mathematical tasks, which leads to further avoidance [1, 5].

When learners have a preconceived notion that they dislike mathematics and will not succeed in the course, it can be challenging for educators to motivate and actively engage them with learning mathematics. The research question that we seek to address in this paper is: "How can we motivate students to overcome fear and engage actively with learning mathematics?" This paper reports on the findings of an action research project where two key interventions were made (1) involving students as instructional resources and (2) giving students shared ownership of their assessments to enable them to overcome the fear of mathematics.

Section 2 describes the setting of the study and the need for learner ownership. Section 3 explains the methodology followed for this study. Section 4 presents the

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design of a teaching approach to promote student ownership, and its implementation is described in Section 5. In Section 6, the findings of the study are discussed. Section 7 provides a conclusion followed by future recommendations.

2. SETTING AND BACKGROUND

This study was performed at a New Zealand tertiary institution with students enrolled in the *Mathematics for Information Technology* course, undertaken in the third semester of their undergraduate study. This course is mandatory for all students enrolled in the Bachelor of Applied Information Technology program, and I was the sole instructor for this course. Learners were a mixed group of students coming directly from secondary school (approximately 50%) and adults with industry experience returning to upskill and qualify. The course was run over a 16-week semester as a flipped classroom with a 2-hour lecture and a 2-hour workshop session each week. The lecture session required student participation, and the workshop sessions engaged learners to develop their practical problem-solving skills further.

Learners had access to quality self-directed learning resources on the e-learning system, in the form of (1) a course handbook with guided instructions and worked examples, (2) web-based content such as 2–5 minute videos by me (to give a personalized feel), video links to other sites, links to other resources, and (3) web-based review quizzes, mock tests, and online discussion forum. There was an expectation that the learners would study and attempt the web-based quizzes before attending the lectures. While their e-learning engagement could be tracked, there was no system in place to hold learners accountable for engaging with these activities. The problem I faced was that learners did not "like" mathematics and hence, did not want to engage with the course any more than during the class times. To master mathematical concepts, purposeful engagement from students is essential in addition to hard work [9].

I reflected on my personal experiences as a student, especially on aspects that helped me develop a passion for mathematics. As a student, while I never considered myself a mathematics expert, my peers often approached me during exam study times to clarify concepts as they perceived that I gave them a straightforward explanation and/or a different method of solving the problem. Although the tasks were challenging, getting support from someone they trusted and the prospect of scoring well in the assessments gave them the determination to persevere. While my peers benefited with my guidance, I not only improved my retention of the material but also developed confidence and started enjoying maths. I wanted to develop a similar passion and confidence among my students.

The key intervention I planned was to involve students as learning resources through peer engagement. Learning is more effective when learners encourage and help each other, discuss solutions, challenge each other's reasoning, and explore more than one way of solving a problem [4, 8]. Learning from peers is beneficial as it gives learners another perspective of solving a problem [1, 8]. Peer interactions within the classroom allow for more opportunities for communication among

the learners, more personalized learning experience, and a healthy and supportive learning environment [1].

The other intervention I planned was to prompt learners to become active participants by taking shared ownership of their assessments. Learners could choose to attempt the assessment early when they mastered the topic. This flexibility allows learners to take responsibility, reflect on their learning, and consequently be more involved with their learning. Two concerns arise from this (1) why would learners want to be assessed early? and (2) how would learners attempt the assessment early when they may not have learnt all the topics yet?

The solution to the concern about early assessment is to prepare learners, so they feel confident and ready to be assessed. Create several opportunities to provide feedback. Simulate a test environment using rehearsal tools to assure their learning and improve their confidence. Giving learners guidance, feedback, and opportunities will enable them to make incremental progress towards success [9]. Web-based quizzes can be attempted multiple times, and learners can receive immediate automated feedback. Assessments should not be something to fear and should promote learning and improve performance, not merely to audit it [10].

To resolve the concern about learning the topics for early assessment, learners could attempt the test for a specific topic, as topic-test, instead of the complete test. Learners could take ownership and be responsible for deciding when they were confident to be assessed for a topic. This would mean that the tests are smaller, and the topic is recently covered. To ensure learner's retention when they attempt assessments fresh after they have learnt it, they must demonstrate their readiness for an early assessment by teaching the topic to their peers. When learners are involved with teaching, they have to organize the material, present it, and clarify any queries that may arise. This will not only endorse their knowledge but also ensure their retention of the material. Since not all learners may be brave enough to teach in front of the class, they should be allowed to take the lead in the comfort of their group or get a buddy along to teach the class. Also, the instructor must be watchful and ensure that a safe environment is created in the classroom, primarily because of the varying levels of skills and personal preferences of learners. Learners should be allowed to present their strategies, make mistakes, and discuss freely without putdowns. A nurturing environment will allow learners to feel more relaxed and encouraged to ask questions freely, which helps improve their understanding of the subject [2].

3. METHODOLOGY

This study presents the implementation and findings of a teaching approach that enabled learners to take ownership and actively engage with mathematics. Based on my personal and professional experience, and supported by the literature, the design tenets of the new teaching approach were developed. A mixed-methods approach was followed to collect students' perception of their learning. I implemented the approach for the first time in 2018 second semester (2018–Sem2), and

for the second and third time in 2019 first semester (2019–Sem1) and 2019 second semester (2019–Sem2) respectively with slight modifications. The results of the survey, the interviews, and students' academic performance were analyzed. Based on the analysis, conclusions were drawn, and recommendations made for future study.

3.1. Ethics

The institute where this study was performed has an Ethics Policy and Procedure. Since this research involves human participation, direct interaction with participants, and observations within a research context with the intent to publish findings, I sought and obtained ethics approval from the institute's ethics committee [7]. In line with the institute's ethics guidelines, participants were provided with precise information on the purpose of the survey and interview. Written consent was collected from those who agreed to participate in this study.

3.2. Data Collection Methods

Data for quantitative analysis was obtained through an anonymous survey. All students enrolled in the mathematics course were invited to participate in this study. The survey was anonymous and administered at the start of the semester and the end of the semester. A semi-structured informal interview was conducted at the end of the semester.

4. DESIGN OF THE APPROACH

The aim of creating a new teaching approach was to increase student ownership, so they would feel excited and motivated to learn mathematics and overcome their fear of failure. The new approach was based on two key aspects: (1) involving students as instructional resources and (2) giving students shared ownership of their assessments. The expected outcome is that learners will have higher levels of autonomy. The design tenets are described in Table 1.

This approach assumes that taking responsibility for their assessments will prompt learners to utilize interactive learning opportunities and become active participants.

5. IMPLEMENTATION OF THE APPROACH

The lecture sessions were utilized for learners to lead and teach their peers while the workshop sessions reinforced their learning and were followed by assessments. Learners that chose not to attempt the assessment could leave the session early.

Table 1. Design tenets of the new teaching approach.

Method	Description	Expected benefits
Students as instructional resources	Peer instructions can be powerful. Encourage learners to share their knowledge with their peers by teaching – in pairs, in groups, and eventually to the class	Learning by teaching is a very effective way to understand the underlying concepts of any subject, especially mathematics; When peers lead the classroom session, it helps maintain an informal and relaxed learning environment; When a learner is responsible for not only their own learning but also for helping their peers, it creates a sense of achievement and develops their self-confidence; Knowing that they are contributing to the classroom activity will motivate learners' to work on the topics; Teaching others helps with knowledge retention, gives a sense of achievement, and enables students to overcome anxiety about the subject
Flexibility with assessments	Allow learners to take ownership of their assessments. Allow them to encounter frequent and smaller assessments. Let them decide when they feel confident that they have mastered the topic and are ready to be assessed	Encourages learners to take responsibility for their learning; Motivates learners to engage with the topic to attempt the assessments early and reduce their workload towards the end; By attempting the assessments early, they can receive feedback early; Removes the "pressure cooker" effect as they can choose to attempt smaller components when they are ready; Gives learners self-confidence when they can choose to attempt the assessment when they master it. This improves the chances of success and success reduces fear of failure

5.1. Students as Instructional Resources

Peer instruction was a key component of this teaching approach. To exhibit their readiness for early assessment (details in Section 5.2), learners volunteered to peer teach the topic, with the instructor validating. We maintained an informal setting in the classroom where any learner could volunteer to take the lead. Sometimes, a student wanted assurance before leading the class, and I reviewed their strategy. This made them feel safe and gave them the confidence to share it with the class. When multiple students volunteered, I allowed them to present it together when they were using the same strategy or present one after the other when their strategies were different. This gave learners multiple methods of solving a problem. The peer tutor also checked learners understanding by creating questions and getting learners to solve them on the board. This was crucial as it provided an opportunity for the learning peer to come up to the board and share their solution. They could do so on their own or seek a buddy for support. The aim was to help learners shed their inhibitions and get comfortable with solving problems and explaining the solutions.

Solving the problem for the class not only assured the learners of the correctness of their understanding but also gave them confidence. They then proceeded

Table 2. Assessment schedule – previous model and the new model.

Previous model	New model (as topic-tests)	Deadline
Test 1 (20%) Logic	1. Propositions (7.5%) 2. Predicates (12.5%)	Week 4
Test 2 (30%) Sets and functions	3. Set theory (7.5%) 4. Functions (12.5%) 5. Matrix (10%)	Week 8
Test 3 (20%) Combinatorics	6. Counting (10%) 7. Permutations & combinations (10%)	Week 12
Test 4 (30%) Probability and statistics	8. Probability (15%) 9. Binomial probability (BP) (6%) 10. Cumulative BP & deviation (9%)	Week 16

to create a new question for their peers to solve. This created a chain of iterative problem solving with repetition and variation. When learners saw their peers overcoming fear and mastering the topic, it inspired them to get involved as well. My role shifted to that of interacting with the learners as a mentor and validating or clarifying the content of the session, now run by the learners.

When the peer tutor was engaging the class, I sat among the learners and helped struggling students. I validated their solutions and encouraged them to share it with the class, albeit a small component of the topic. Knowing that their answers were right before sharing it with the class gave them confidence, and the option of presenting with a buddy put them at ease.

Sometimes the peer tutor would need corrections, and these were made by the peers' or by me without any putdowns. Allowing learners to make mistakes and reinforcing the idea that this is acceptable made learners feel safe, and there was no resistance by students about being wrong. By week 3, most of the learners voluntarily participated, either in their groups or by leading the class. Sometimes one or two learners did not participate in the session because they were having a bad day, but this was not a regular occurrence.

5.2. Shared Ownership of Assessments

Learners had the choice of "how much" and "when" they chose to attempt an assessment. Learners had access to web-based quizzes, mock tests, and online discussion forum. Queries on the online discussion forum were responded by both peers' and me. All web-based quizzes and mock tests provided instant automated feedback. These not only simulated a test environment but also allowed them to check and be confident of the topic, or correct any misinterpretations.

The course had 10 topics and originally had 4 supervised tests. The new assessment model had 10 *topic-tests*, each topic-test relating to a specific topic. The old test schedule was used as a guide to determine the deadline before which each topic-test had to be attempted. Table 2 shows the assessment schedule as topic-tests, its contribution towards the course, and the deadline.

Learners could choose to attempt one or more topic-test at a time, but each topic-test could only be attempted once. Learners were required to attempt all

the topic-tests on or before the deadline (details in Table 2). For example, 1-Propositions test and 2-Predicates test could be attempted any time between week 1 and week 4, together or separately, and in any sequence.

With tests run more than once, to maintain the integrity of the assessments, multiple versions of the tests were created. In doing so, no two occurrences had the same questions. The web-based mock tests not only served as a rehearsal tool but also prevented learners from asking questions of those who had previously attempted the test. Students were required to demonstrate that they were ready for an early assessment and were encouraged to score at least 90% in the mock test to discourage unprepared attempts.

5.3. Improvements Made to the Approach

When this approach was implemented in 2018–Sem2 and 2019–Sem1, a small number of students chose to work on the previous topics, and they did not contribute to the classroom discussions. To prevent students working on separate topics, the assessment model was modified in 2019–Sem2 such that the learners had the choice to attempt the topic-test either in the following workshop session or on the deadline date, but not in between. This ensured that all learners were working on the same topic during the classroom sessions.

6. FINDINGS AND DISCUSSION

The new teaching approach was implemented for three consecutive semesters: 2018–Sem2; 2019–Sem1; and 2019–Sem2. From a total of 80 students (31, 28, 21 enrolled students each semester, respectively), 68 students (24, 24, 20 students respectively) agreed to participate in this study.

6.1. Student Confidence with Mathematics

A comparative analysis of student confidence with mathematics topics was performed. Question 1 of the survey required students to reflect on their confidence with mathematics topics on a scale of 1–10 (1 – Do not know anything to 10 – Very confident) at the start of the course, and again at the end of the course. Student responses are as shown in Figure 1.

The quantitative feedback on the approach showed improved confidence in mathematics with learners' average confidence increasing from 6.62 at the start of the semester to 7.86 by the end of the semester. Due to the anonymous nature of the survey, a statistical test of significance could not be performed. I observed that by the end of the semester, learners were more comfortable to discuss mathematical concepts and sharing ideas with peers became a norm.

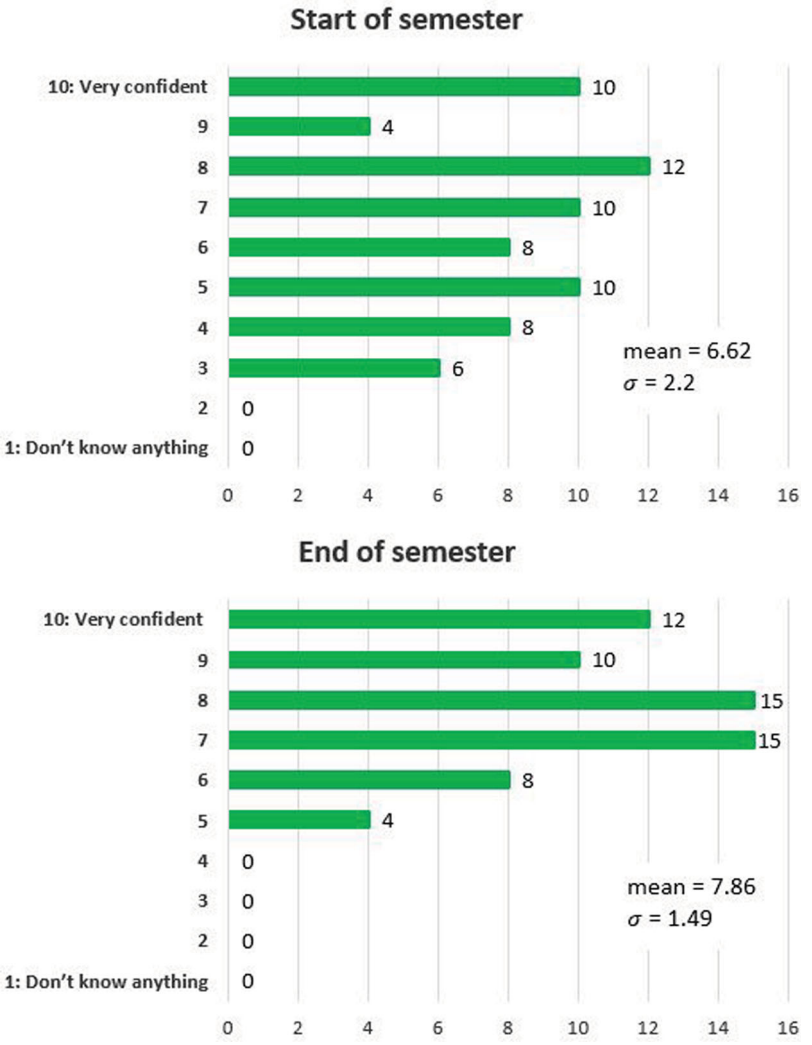

Figure 1. Student confidence with mathematics at the start ($N = 68$) and end ($N = 64$) of the semester.

6.2. Perceptions of the Approach

Question 2 of the survey required students to rate their satisfaction with the teaching approach on a scale of 1–4 (1 – Is not working for me to 4 – Is working really well for me) at the end of the semester. Their responses were as shown in Figure 2.

All participants agreed that the approach worked to at least some extent. Nearly 87% of the participants thought that the approach worked well or really well for them. None of the students expressed dissatisfaction with the approach. This indicates that students are willing to engage and take ownership of their learning, even for courses they perceive to be difficult when they feel supported.

Student responses to "Why is this approach working (or not working) for you?" indicated that making the class informal by getting peers involved in teaching the class made learning joyful, engaging, and rewarding. Learners responded that

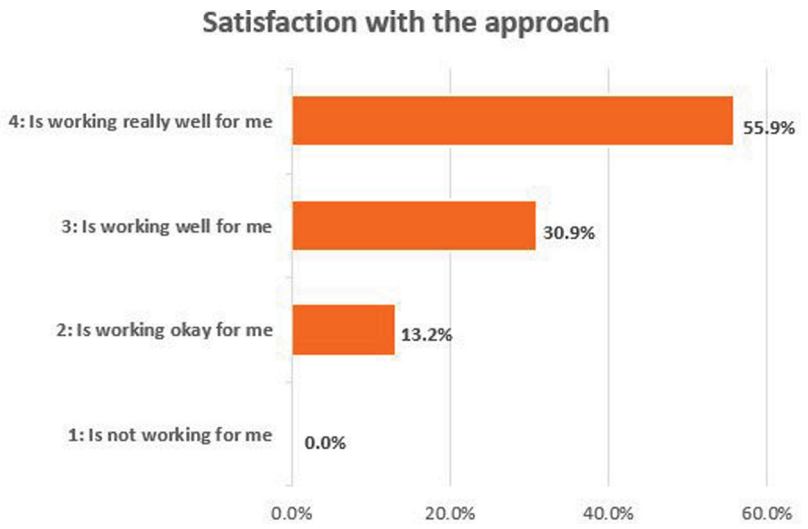

Figure 2. Student satisfaction with the approach ($N = 64$).

they felt more inspired to make contributions when their peers appreciated their input compared to a traditional classroom setting. Some learners responded that clarifying peers' queries improved both their confidence and performance and hence were motivated to study so they could continue contributing. There were no negative responses. Some of the responses were:

- *I loved the challenge of coming up with the questions for the class to work on.*
- *The classes were wonderfully rewarding, and it improved my performance and confidence.*
- *I hated studying math before studying from Sunitha. After studying from Sunitha, I started liking maths.*

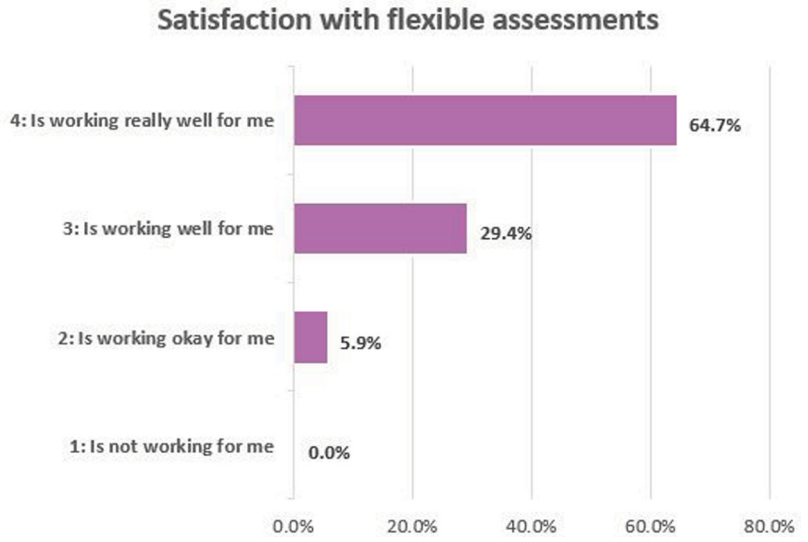

Figure 3. Student satisfaction with the assessment design ($N = 64$).

The apparent benefit I observed was that in this teaching approach, the classroom session served to reinforce learners' understanding rather than their initial point of content exposure. As intended in the design framework of this teaching approach, leading the class gave the learners self-confidence, and it helped overcome the fear of failure. Watching their peers being corrected without putdowns, assured learners, even the struggling ones, that it was okay to make mistakes. By the third week, most of the learners voluntarily participated. As suggested by Attard [1], Retnowati, Ayres, and Sweller [8] and Simms et al. [9], engaging students as learning resources was beneficial for both the learner and their peers. I observed that the learners also engaged more frequently with e-learning resources. The improved learner engagement indicated that it is not just the instructions and videos on their own, but how they are integrated into an overall approach that makes a difference.

6.3. Perceptions of Assessments

Question 3 of the survey required students to rate their satisfaction with the shared ownership of assessments on a scale of 1–4 (1 – Is not working for me, to 4 – Is working really well for me) at the end of the semester. The responses were as shown in Figure 3.

Student's perception of assessment design was positive, with 94% of participants agreeing that the assessment design worked well or really well for them. All the participants were satisfied with the assessment design, and none of them perceived that it did not work for them.

Student responses to "Why is this assessment method working (or not working) for you?" indicated that flexibility with assessments allowed them to stay focused and learn the topic to output higher quality work. Learners perceived that it reduced the situation for overload and mental stress associated with a traditional single-shot effort at the end of the course. Learners felt that smaller assessments were easier to prepare for, and hence they were more confident. One student responded to the model to be overloaded with assessments but did not rate it unfavorably in the quantitative survey.

The main benefit of learners taking shared ownership of assessments was that they took the responsibility to self-evaluate and determine whether they were ready to be assessed. I observed that they were less fearful and more willing to persevere and engage with their learning when they had the choice to decide. This design framework intended to give learners ownership of their learning, and the outcome was that learners were interacting actively, seeking feedback frequently, and were more relaxed as they prepared for their assessments.

6.4. Results from Student Interviews

Interviews with participants are ideal for data collection in qualitative research, especially with small sample size. Although similar data can be collected through the survey questionnaire, interviews facilitate the gathering of further information to verify and/or embellish the findings [3]. I conducted short (5–8 minutes)

semi-structured interviews. The participants could choose to be interviewed by themselves or in small groups. An audio recording of each interview was made. The responses are summarized as follows.

Students reflected that leading the session with a buddy helped them feel safe, and it gave them the confidence to engage with the classroom activities and help others in the process, even though they were novices.

> *As an adult student coming back to education, I had a real phobia of maths as I hadn't done so well with maths in high school . . . I really enjoy the way we have the group work where we put the problems on the board, and we all work through them as a group which means we can help each other out as well.*

Encouraging learners, without being forceful, to work with a buddy or a group allowed more peer engagement during class times. It gave them the "can do" attitude and confidence that empowered them to overcome fear.

> *The way that the interactivity is done here when everyone does teaching, and everyone can go up and do the questions, it means there's a lot more going on in the class, people are actually talking and discussing, and people are actually participating and asking questions, which I think is a nice way.*

Being able to peer teach and clarify peers' queries, made learners not only understand the concepts and be confident with the topic, they felt valued.

> *The best way to learn something is to actually teach someone. Because you actually have to understand, you have to know what you are teaching them. I like these classes because others listen to me, and I make a difference to them.*

Having the choice to attempt the assessment when they were ready, motivated learners to work on course activities.

> *Going to a test with the information that I have fresh in my mind means that I can answer the questions that are asked of me during the test with confidence. It allowed me to stay focused and prepare for the class.*

Learners felt that peer teaching under a watchful instructor allowed them to gain a deeper understanding of mathematical concepts. They felt that they were seen as individuals and that the instructor "cared" about their learning.

> *I found your teaching style very helpful, and it comes across that you actually care about how we do. That helps a lot . . . Even though you were sitting in the class and watching what was unfolding in front of you, the learning was still happening, and everybody was enjoying themselves. So going to those classes was good. It was still class for us, but it was a fun class.*

Learners thought that this model provided several opportunities to have substantive conversations with the instructor. The general feedback from most of the learners was that they needed to "like" their instructors in order for them to "like" maths.

6.5. Student Achievement

Students' academic achievement was analyzed based on the class results. I compared the results over six consecutive occurrences of the course. To have a fair comparison

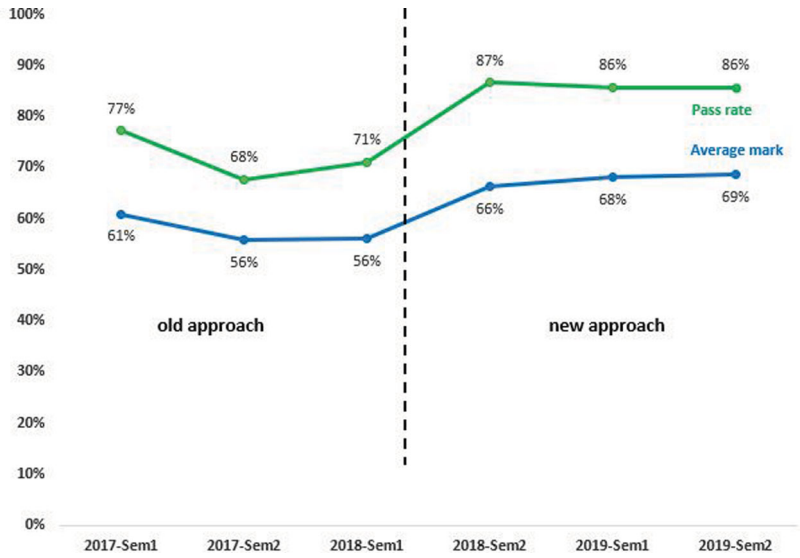

Figure 4. Pass rates and average mark over six consecutive occurrences of the course.

of performance across semesters, similar assessments were used for 2018–Sem1, 2018–Sem2, 2019–Sem1, and 2019–Sem2. Figure 4 shows the pass rates and average mark for the course across six consecutive occurrences, the last three using the new approach.

It can be seen that the pass rates and the average mark improved with the new approach. An ANOVA showed a significant difference among the six cohorts of students with $F(5, 208) = 3.166, p = 0.009$. However, posthoc Tukey test did not yield a practically significant result. My observation was that the learners took responsibility for balancing their workload and attempted the test when they were confident with the topic, resulting in better performance and grades.

7. CONCLUSION AND FURTHER STUDY

The outcomes of this approach match and exceed the anticipated benefits of the theoretical framework. The most significant benefit of involving students as instructional resources was that learners actively engaged and took ownership of their learning. Learners not only enjoyed solving math problems but also developed the confidence to help peers. As intended in the design framework of this teaching approach, learners had the opportunity to learn different ways of solving problems. Some additional unintended benefits were that I had more time during the classroom session to engage with struggling learners as I was no longer the only instruction provider during the sessions.

Shared ownership of assessments allowed learners to be responsible and prepare for the assessment. Learners were more relaxed and less fearful when they perceived that they were ready for the assessment, as intended in the theoretical framework. When learners saw that they could score well in their assessments, it gave them

joy and confidence to "like" the course. Taking ownership of their learning and assessments promoted a sense of achievement and consequently, promoted learner engagement with mathematics.

Struggling students will still need encouragement and support to engage with online material and in-class activities. Some learners may not swiftly adapt to the new teaching approach, especially being brave enough to teach their peers. The instructor will need to be persistent and keep encouraging learners.

Although this study was conducted exclusively with mathematics, the findings and recommendations could be applied to other tertiary and higher education courses. A limitation of this study is that it was conducted at a single institution in New Zealand. This limitation could be removed by conducting a more extensive study across multiple institutions. It would be interesting to observe whether there are similar trends at other tertiary institutions.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

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BIOGRAPHICAL SKETCH

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