

Flipping the Script: Reflection on Implementing the Flipped Classroom in Mathematics

Nawal Chanane*, Jiansheng Cui*, Catherine Hassell Sweatman[†], Victor Miranda[†], Nuttanan Wichitaksorn[†],
Wenjun Zhang[†], Patricio Maturana-Russel[†], Robin Hankin[†], and Roopak Sinha[†]

*AUT Learning Transformation LAB: {nawal.chanane, jason.cui}@aut.ac.nz

[†]School of Engineering, Computing and Mathematical Sciences,

Auckland University of Technology (AUT), Auckland, New Zealand.

{catherine.sweatman, victor.miranda, nuttanan.wichitaksorn, wenjun.zhang, p.maturana.russel,
robin.hankin, roopak.sinha}@aut.ac.nz

Abstract—With the world moving forward, leaders in the university sector must proactively innovate in the delivery of teaching programs. The way students learn is changing, such as reduced lecture attendance and a growing demand for digital learning. This impacts staff workload and can negatively affect both the in-class and online student experience. We need to find ways to enhance student learning and engagement in an attendance-agnostic manner. In this work-in-progress paper, we describe the process of re-designing three courses from the Mathematical Sciences Department at Auckland University of Technology using the flipped classroom and active learning pedagogies. We reflect on the implementation of these courses, which were flipped for one semester (12 weeks) with students who had no previous experience with flipped learning. Despite challenges in involving students in pre-class tasks due to their unfamiliarity, positive feedback on lecture recordings and scaffolding of activities was received from motivated students. Future enhancements of each course will be incorporating students' feedback and the lessons learnt from the course's first run.

Keywords—*Flipped Classroom, Motivation, Students Engagement, Active Learning, Math Courses*

I. INTRODUCTION

In recent years, the demand for innovative instructional methods has surged, particularly in math education. The flipped classroom model is one of the approaches that stands out in this regard [1], [2]. Students are expected to learn new content online before class, while classroom time is dedicated to engaging in active learning activities. Different flipped models have been proposed and implemented in specific areas; the conventional flipped classroom emphasizes content delivery [3], while others suggest progressive activities, diversified platforms, and engaging experiences [4]. Previous studies [5] have demonstrated its positive effects, including promoting students' learning performance and satisfaction compared to traditional classrooms. However, some studies have found no difference between the flipped and traditional classrooms. Thus, ongoing discussions persist regarding its impact [6].

Traditional lecture-style teaching in mathematics presents challenges. Students struggle to comprehend complex mathematical concepts within limited class time, while lecturers find it challenging to offer personal support. The flipped model addresses these issues by delivering content outside of the classroom, enabling self-paced learning and more engaging in-class activities [7]–[9].

The way students learn has significantly changed, especially post-COVID, affecting attendance at our university in sessions where one-way theory or content is delivered. This necessitates the need for a more innovative approach. Feedback from students, school leadership, and the Learning & Teaching Committee raised questions and queries regarding

the flipped model. One concern was that students may not see academics, potentially affecting their learning experience. In response, students will be expected to conduct on-campus labs, workshops, and tutorials. Out-of-class support includes office hours and other mechanisms, such as a study zone offering drop-in peer mentoring. Introducing any new teaching approach requires a comprehensive understanding of its implications, challenges, and implementation needs. This paper offers valuable insights into our experience in transforming the traditional learning environment into a dynamic and student-centred knowledge acquisition and exchange.

Our reflective paper follows this structure: We begin by discussing the literature surrounding the flipped classroom model and its use in mathematics courses. We then explain the employed methodology and the context of the study. Next, we introduce the three courses and reflect on our experience designing and implementing them. Finally, we will conclude with recommendations for future work on the project.

II. LITERATURE REVIEW

Innovative teaching methods have brought flipped classrooms into the spotlight in recent years. The traditional method of teaching through lectures is replaced by preparatory material such as readings, pre-recorded video lectures or online resources that students are expected to complete before class. This, in principle, allows for more interactive and collaborative activities during class time, which might lead to deeper learning. Lecturers often adapt the flipped classroom model based on factors like class, content, and student needs [10]. Studies [11]–[13] have supported many benefits of this method for students, including enhanced interaction and insight into learning progress. Shifting passive learning out of class enables active engagement through collaborative problem-solving, peer assessment, and hands-on exercises, improving academic achievement [2], [7], [9].

Various studies have explored flipped classrooms' impact on math learning outcomes and engagement. For instance, a study on first-year math students showed improved performance with the flipped approach [12]. However, the researchers suggested conducting further research to assess if this approach affects attrition, retention, progression, and graduation rates. Another study [14], examined multiple math-focused flipped classroom studies, revealing three key benefits: more in-class time for practice, integrating new knowledge with existing beliefs, and real-time feedback. The two main challenges reported were students' unfamiliarity with flipped learning and the substantial implementation effort. In conclusion, research indicates improved learning and engagement with flipped classrooms. Nevertheless, it is crucial to note that this teaching method may not be suitable for all students or subjects, and it demands rigorous planning.

Additionally, not all students have reliable access to technology and resources outside of class, and some may struggle with self-directed learning. Without clear and explicit guidance, students may feel overwhelmed, confused, insecure, or disoriented [15].

III. METHODOLOGY

In this paper, we reflect on our experience of implementing flipped classroom and active learning pedagogies to redesign three mathematics courses—one in the first semester and two ongoing. For the initial run, six lecturers and two designers collaborated. The learning designers worked on the process, prepared templates, examples, and guides, and delivered workshops to guide the lecturers through the transformation of their courses and reflected on feedback. The team of lecturers redesigned the content and implemented the changes required on Canvas with the support of the learning designers during a 12-week design cycle. This paper presents their reflections on the course implementation, successes, and future improvements.

Our course design adopted a flipped classroom model from Karanicolas, Snelling, Kemp, & The University of Adelaide Flipped Learning Community of Practice (Fig. 1). They described the flipped classroom as "an engaging series of learning segments, that are closely linked to learning and assessment outcomes, that provide feedback to the learner during each stage. Carefully designed pre-class activities assist students in learning key concepts in a self-paced manner, developing their confidence and motivation to engage in peer-led discussions during class that lead to synthesis and application of these key concepts. Post-class assessment activities are clearly connected to pre-class and face-to-face class learning experiences and address 'capabilities that count,' making the students' learning relevant, real and sustainable". For the one-hour face-to-face time with students, we incorporated the active learning pedagogy. We adapted the Active Learning model from the University of Illinois Urbana-Champaign to suit our needs [15]. The learning designers developed a step-by-step guide to aid lecturers in course design. This model was chosen for its alignment with session goals and assurance of meeting learning expectations through reflections and closing the loop of feedback.

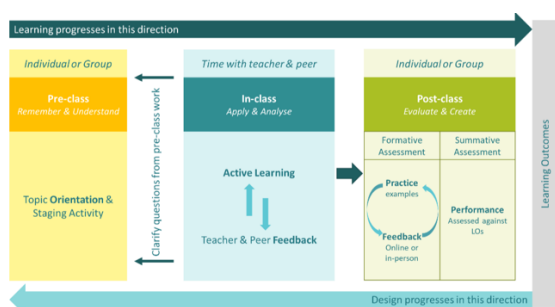


Fig. 1. Flipped classroom model adapted from Karanicolas, Snelling, Kemp, & The University of Adelaide Flipped Learning Community of Practice.

IV. COURSE DESIGN

Our approach to the flipped classroom model focused on providing clear guidance, promoting student engagement, encouraging active learning, and striving for continuous improvement. We followed a four-stage process, beginning with cultivating ideas and creating a blueprint. Lecturers used provided resources and templates to shape their approach, taking into account principles such as providing students with

opportunities to engage with key ideas before class, incentivizing students to prepare for class, and assessing student understanding. They also reviewed the structure of their course delivery throughout the semester, gaining insights into the pre-class, in-class, and post-class phases of a flipped classroom [16].

Next, we aligned the online content with the blueprint, encouraging lecturers to create a clear path by integrating explicit guidance and structure. We used a Canvas structure template to ensure a consistent learning experience. The third stage is about realizing engagement through active learning in class. For example, students recapped their pre-class learning, practised and applied knowledge, and engaged in a set of active learning activities, such as problem-solving, peer instruction, discussion, and simulations.

Finally, the most important step in closing the loop was enhancing through reflection. As best practice, we reflected on our practice, identifying successes and areas for improvement. We continuously evaluated the effectiveness of the flipped classroom model and made necessary enhancements. Our reflections on practice were about reconsidering the situation after it happened and thinking about what needs changing for the future run of the courses.

V. IMPLEMENTATION

A. Pilot Course - Statistics for Data Science

1) *About the course:* This level-6 course is designed for second-year undergraduate students, introducing them to the mathematical and statistical foundations crucial for data science and machine learning through practical applications and the utilization of statistical packages. The course was delivered to 121 students, divided into four sections, each comprising around 30 students. Two sections were run by professional research-active statisticians; the remaining two were run by a teaching assistant. Key statistical concepts covered included statistical inference as well as linear models. The assessment plan encompassed an invigilated mid-semester test, coursework comprising a case study and practical exercises, and a final invigilated controlled assessment. Feedback for those assessments was provided on Canvas. The assessment solutions were posted on Canvas in due time.

2) *Reflections from lecturers:* Students' views on the new modality focused on the unexpected replacement of the traditional live lecture with pre-recorded asynchronous and generic online videos. As the course lecturers, we highlight significant obstacles stemming from the lack of in-person interaction with students, potentially leading to comprehension and motivation difficulties. We stress the essential role of face-to-face content explanation for students, noting the value of personal interaction and the ability to observe student understanding. This direct connection allows us to adapt explanations when it becomes evident that certain concepts are not resonating with students. However, we were unable to reproduce this personalized approach when students interact with the online material independently. Encouraging students to complete pre-class tasks, such as watching instructional videos or solving problems, proved to be exceptionally challenging. Consequently, active engagement with the course content occurred almost exclusively among

high-achieving students. The students restricted their active engagement to activities that attracted course credit, such as formative assessment items. Many students appeared to find the first in-person examination distressing due, we think, to lack of personalized involvement with the course. Overall, comparing traditional delivery methods to alternative approaches did not yield any noticeable improvement in student performance. In fact, weaker and stronger students alike seemed to be negatively impacted. Despite some encouraging findings in previous studies, our own observation did not reveal any significant improvement in student achievement using the same model.

B. First Cycle Courses

After conducting the pilot courses and collecting feedback from the lecturers and learning designers, the decision was made to reinstate the one-hour face-to-face session with students. The design process included the preparation of active learning sessions. The subsequent two courses were Forecasting, a level-6 course delivered to first-year students, and Engineering. Therefore, Maths III, is a level-7 course catered to second-year students.

1) Forecasting

a) About the course: This course is intended to provide a comprehensive introduction to forecasting methods and to present enough information about each method for readers to be able to use them sensibly. We look into several forecasting methodologies for univariate time series with applications in fields like business and economics using the Statistical Software R, including time series regression, Exponential Smoothing and ARIMA models, as well as cross-validation techniques for forecast accuracy. Upon completion, students will be able to (a) identify and interpret the main features of univariate series, (b) use appropriate methods for forecasting-models selection, and (c) correctly employ the R statistical software for this purpose. The assessment plan comprised weekly labs and a final invigilated assessment.

b) Reflections from lecturers: Since its implementation early this year, several concerns have been raised about the effectiveness of the flipped classroom approach, especially given that students are performing very well under the traditional teaching method. The semester is halfway through, and we still do not have enough evidence to draw conclusions, let alone engage in discussions on potential limitations and advantages of this teaching approach for a paper that demands specific mathematical and computing skills. While two-hour lectures might not be necessary for students to fully grasp concepts, we strongly believe that communication plays an important role in delivering this paper meaningfully, enabling students to comprehend the fundamentals and, in the short term, be able to develop self-learning skills and prepare independently.

This semester, still in its testing phase, 'Forecasting' sees the introduction of a one-hour face-to-face session plus a two-hour lab, providing an opportunity for an enhanced flipped classroom experience. We employ focused materials and facilitate interactive discussions with real-world applications to address student queries and foster a better understanding of the concepts. Through peer-to-peer learning and the incorporation of formative assessments with prompt feedback, we expect students to have a significant learning experience—

at least as significant as that from the traditional teaching method.

2) Engineering Maths III

a) About the course: This course teaches analytical and mathematical methods for modeling engineering systems. Students will learn to convert practical problems into equations, identify different equation types, apply boundary conditions, and solve complex equations through analytical and numerical methods. The course has weekly quizzes, a mid-semester test, and a final assessment. At the time of writing this paper, the course is half-way with six weeks completed and a mid-semester exam is on the way.

b) Reflections from lecturers: We were keen to switch to a flipped classroom model, yet we were anxious about accurately assessing the students' mathematics proficiency. We believe that students required more one-on-one time with lecturers to comprehend mathematical concepts, not only due to their unfamiliarity with self-directed learning but also because many students struggled with even the most basic mathematical concepts. In an effort to align with the flipped classroom approach, we pre-recorded weekly video lectures to be more concise and detailed, adhering to best practices. Despite the efforts to incorporate comprehensive explanations and straightforward guidance for students (Fig. 2), we remain hesitant about fully adopting the flipped classroom model, fearing that it may negatively impact student outcomes. We anticipate that we will have to reiterate content to students individually during the lab or office hours. Additionally, are unsure how best to support Teaching Assistants (TA) in embracing the flipped model within the lab setting. These concerns were shared among most lecturers during both the pilot and flipped classroom cycles. However, it is worth noting that the weekly quizzes were popular, students felt that by doing the quizzes, they are focussing on what they need to learn. The students' engagement was good, and the students received high marks. The attendance to the face-to-face one-hour session was not high, around 30%, we expected more students attending. However, the course is half-way through, so our next step is to monitor the second half of the semester and see how students will go with the content and assessments.

To Do

We have one joint class with the lecturer (for everyone) and one tutorial (per stream) per week. Both of these are problem-solving sessions. Come to your joint class to discuss the exercises in the lecture notes and videos. Ask questions and contribute a lively discussion. Come to your tutorial to extend your problem-solving experience and get individual attention.

Before the joint class and your tutorial

- Go through the pre-class content and activities
- Read Chapter 12.1, 12.2, 12.3, 12.6
- Post your questions to the weekly [discussion board](#) so we can address them in the joint class.
- Work through the tutorial questions. Bring these questions to your tutorial and ask for any help that you need.

During class

- Attend the joint problem-solving class, be prepared to work through the **exercises found in the lecture notes**, bring your laptop and ask questions.
- Attend your tutorial, work through the **tutorial worksheet** and engage in in-class activities. Bring your laptop and ask questions.
- Complete the tutorial task.

After class

- Review materials of the week and check your understanding.
- Complete the short Quiz 8. **These short weekly quizzes are graded** and the marks contribute to the assignments.
- Refer to the content for next week and complete your preparation.

Fig. 2. To-Do steps for students

VI. REFLECTIONS ON IMPLEMENTATION

In general, recent changes have been positively received by motivated students, as evidenced by their active participation in classroom discussions and online Q&A channels such as Canvas communication. This echoes findings from studies [13] that highlight the favorable response to flipped learning from academically competitive students.

Video viewing rates mirror lecture attendance in time-sensitive content, though variability exists across courses. Attendance and online interaction, including discussions and watch rates, also exhibit noticeable variations. Interactive online discussions achieve greater success when offering rewards or addressing engaging topics. However, concerns persist about the scalability of activities, low engagement of a large but silent group, and challenges linked to student self-discipline and video comprehension. Further effort is required to address students less inclined to self-study, hesitant to ask questions, or attend tutorials. Some students prefer traditional teaching due to knowledge gaps or motivation issues, needing extra monitoring and guidance. Subject matter was another key factor. Some students found learning statistics from videos challenging and they requested immediate in-person clarifications. Math symbols in manuals and handouts troubled those without relevant backgrounds. Additional face-to-face explanations would aid these students. Students acquainted to traditional delivery may struggle with the flipped classroom. On the other hand, students who work during semesters value the flexibility, learning at their own pace, and revisiting lectures when convenient.

In summary, the pilot delivered marginal benefits that highlights the need to tweak the model. Feedback from lecturers has led to re-introducing a weekly 1-hour all-of-class session for students. Students are still expected to self-learn and conduct lab/tutorial work, but this session gives teachers a way to balance the challenges faced in the pilot. Collecting learner and teacher feedback regularly and systematically and refining the model further is a significant endeavor; implementing such an initiative can include various biases, such as confirmation bias in project leaders and anchoring and expectancy bias in teachers.

VII. CONCLUSION

This paper detailed the process of redesigning three Mathematical Sciences courses for the School of Engineering, Computing, and Mathematical Sciences at Auckland University of Technology, New Zealand. These courses were designed to utilize a flipped classroom and active learning approach. They are taught across a 12-week semester to students who had no previous experience with this type of learning. However, encouraging students to engage in pre-class activities proved challenging, possibly due to their unfamiliarity with the flipped classroom model. The project's reception thus far has shown, at best, mixed results amongst both lecturers and students. The pilot fueled conversations and a rethink of how we teach mathematics, which has resulted in adding another way of teaching to our portfolio.

Diverse opinions from lecturer posed challenges during the project. Many lecturers have raised several well-articulated objections to the project which will need to be addressed as the initiative progresses. This diversity allowed tailoring the model to fit courses and disciplines. Through a tailored flipped classroom approach, lecturers can better meet student needs, promoting personalized teaching, despite ongoing challenges. Overall, there is no one-size-fits-all approach to implementing a flipped classroom. However, a

tailored and well-implemented approach could help students learn how to learn, enhance learning skills, critical thinking, problem-solving, participation, communication, and academic performance. Moving forward, we plan to explore effective ways to implement active learning in larger class sizes and gather student feedback via surveys for continuous improvement.

ACKNOWLEDGMENT

We thank the lecturers who attended the workshops and shared their feedback. Their valuable input has contributed to improving the process and delivery of this initiative.

REFERENCES

- [1] D. C. D. van Alten, C. Phielix, J. Janssen, and L. Kester, "Effects of flipping the classroom on learning outcomes and satisfaction: A meta-analysis," *Educ. Res. Rev.*, vol. 28, no. March, pp. 1–18, 2019.
- [2] M. Güler, M. Kokoç, and S. Önder Bütüner, "Does a flipped classroom model work in mathematics education? A meta-analysis," *Educ. Inf. Technol.*, vol. 28, pp. 57–79, 2023.
- [3] X. Dong, "Application of Flipped Classroom in College English Teaching," *Creat. Educ.*, vol. 07, no. 09, pp. 1335–1339, 2016.
- [4] Y. Chen, Y. Wang, Kinshuk, and N. S. Chen, "Is FLIP enough? or should we use the FLIPPED model instead?," *Comput. Educ.*, vol. 79, pp. 16–27, 2014.
- [5] S. Sergis, D. G. Sampson, and L. Pelliccione, "Investigating the impact of Flipped Classroom on students' learning experiences: A Self-Determination Theory approach," *Comput. Human Behav.*, vol. 78, pp. 368–378, 2018.
- [6] R. J. Sparks, "Flipping the Classroom: An Empirical Study Examining Student Learning," *J. Learn. High. Educ.*, vol. 9, no. 2, pp. 65–70, 2013.
- [7] H. Al-Samarraie, A. Shamsuddin, and A. I. Alzahrani, "A flipped classroom model in higher education: a review of the evidence across disciplines," *Educ. Technol. Res. Dev.*, vol. 68, no. 3, pp. 1017–1051, Jun. 2020.
- [8] J. O'Flaherty, C. Phillips, S. Karanicolas, C. Snelling, and T. Winning, "The use of flipped classrooms in higher education: A scoping review," *Internet High. Educ.*, vol. 25, pp. 85–95, Apr. 2015.
- [9] J. Nouri, "The flipped classroom: for active, effective and increased learning – especially for low achievers," *Int. J. Educ. Technol. High. Educ.*, vol. 13, no. 1, p. 33, 2016.
- [10] G. Akçayır and M. Akçayır, "The flipped classroom: A review of its advantages and challenges," *Comput. Educ.*, vol. 126, no. January, pp. 334–345, 2018.
- [11] M. Güler, M. Kokoç, and S. Önder Bütüner, "Does a flipped classroom model work in mathematics education? A meta-analysis," *Educ. Inf. Technol.*, pp. 57–79, 2022.
- [12] N. J. Shukla and E. Mcinnis, "Flipped Classroom: Success with First Year Mathematics Students," *Int. J. Soc. Educ. Sci.*, vol. 3, no. 1, pp. 32–47, 2021.
- [13] M. Cronhjort, L. Filipsson, and M. Weurlander, "Improved engagement and learning in flipped-classroom calculus," *Teach. Math. its Appl.*, vol. 37, no. 3, pp. 113–121, 2018.
- [14] M. J. Sosa Díaz, J. Guerra Antequera, and M. Cerezo Pizarro, "Flipped classroom in the context of higher education: Learning, satisfaction and interaction," *Educ. Sci.*, vol. 11, no. 8, p. 416, Aug. 2021.
- [15] U. of I. Urbana-Champaign, "Planning A Class Session," Center for Innovation in Learning and Teaching, 2023.[Online]. Available: <https://citl.illinois.edu/citl-101/teaching-learning/resources/teaching-strategies/planning-a-class-session>.
- [16] M. K. Kim, S. M. Kim, O. Khera, and J. Getman, "The experience of three flipped classrooms in an urban university: an exploration of design principles," *Internet High. Educ.*, vol. 22, pp. 37–50, Jul. 2014.