

STRATEGIES FOR REAL-TIME FEEDBACK AND INDIVIDUALIZED SUPPORT IN MATHEMATICS LECTURES

Cristina Anton

Department of Mathematics and Statistics, Grant MacEwan University (Canada)

Abstract

Fostering active engagement, rapid feedback, and individualized support are all part of student-centered teaching in higher education. Lecture-based teaching methods often restrict opportunities for meaningful student participation and delay the identification of learning difficulties. This paper examines strategies designed to accelerate feedback mechanisms and provide targeted assistance to support students to learn challenging mathematical concepts, with a particular focus on enhancing participation during lectures. We compare conventional lecture-based teaching with student centered teaching for medium sized classes of introductory calculus. We use quantitative methods based on the students' final percentage formed with the marks for the assignments, term exams, and final examination. The results show that student-centered strategies not only expedite feedback but also transform the lecture into a participatory and dynamic learning environment. Increased student involvement fosters greater ownership of learning, enhances motivation, and contributes to improved academic performance illustrated by a lower proportion of students that fail to pass the course.

Keywords: *Student-centered learning, real-time feedback, individualized support.*

1. Introduction

In undergraduate mathematics courses, concepts can be abstract, and many students find them difficult to learn or un-engaging, so fostering active engagement, rapid feedback, and individualized support are very important. We analyze several approaches that support individualized learning within collective classroom contexts.

Active lecturing is based on strategies that foster student participation and active learning (Gregory, 2013). The positive effects of classroom assessment techniques for teaching effectiveness are well documented (Hanson & Florestano, 2020). This includes increasing student engagement (Adams, 2004; Byon, 2005), facilitating a positive instructor-students relationship (Byon, 2005; Goldstein, 2007), and fostering active student learning (Knight and Wood, 2005; Steadman and Svinicki, 1998; Cottell and Harwood, 1998). Some of the methods commonly used for student engagement are not applicable for mathematics classes. Especially in introductory calculus or linear algebra courses, learning happens on an individual basis rather than in a group, and there is only one correct answer. Thus, open ended questions, discussions, and group work are less suitable for teaching undergraduate level mathematics classes.

Small-group collaborative problem-solving exercises, and low-stakes assessments create opportunities for students to engage with complex material in a supportive environment. These practices allow instructors to identify and address individual learning gaps in real time, ensuring that students receive timely and personalized guidance. Central to these strategies is the integration of real-time formative assessment tools such as short diagnostic quizzes. These approaches enable instructors to monitor comprehension continuously and adapt instructional delivery in response to emerging needs.

In the next section I present the teaching strategies that I used for medium size introductory Calculus classes. In Section 3 I analyze the results obtained applying these strategies. The last section includes the conclusions.

2. Teaching strategies

Here we discuss the results obtained for medium classes class sized using the following approaches:

- Active lecturing and classroom assessment techniques for rapid feedback
- Problem-solving exercises
- Short diagnostic quizzes

The first 2-3 lectures are very important to convince the students that they are in a safe environment and to successfully establish a dialog with them. The questions and the timing during the lecture should be carefully prepared as part of the lecture's dynamics. The first questions usually check the students' mathematical background. To start the dialog, it is a good strategy to ask easy questions first and gradually increase the level of difficulty. Teaching mathematics requires a lot of problem solving. After introducing new mathematical concepts or methods, I use worked examples to illustrate them, guiding students through each step by asking targeted questions that prompt their participation and reasoning. These questions range from quick checks—such as asking for the result of a simple calculation to maintain engagement and verify comprehension—to more challenging prompts designed to probe deeper understanding and identify students who excel. A wrong answer should be corrected, but often the best strategy is to ask multiple questions and help the student discover the correct answer. This approach encourages the students to ask questions, too, and this shows active learning.

Some students, unless they are specifically asked, choose never to answer the questions addressed to the classroom, so active participation is limited to a certain group of students. For medium or large classes, it is impossible to engage each student in every lecture, but there are strategies for fostering active learning that also work for medium and large size classes (Carnegie, 2021; Frederick, 1987; Aronson, 1987). Learning calculus or linear algebra is based on “hands on” activities, and these activities can be included as short breaks from the lecture when students are asked to solve problems on their own. This offers the instructor the opportunity to leave the front of the class and to interact with the students. For some students it is enough to check that they got the correct answer, but for others it is a chance to show them what mistakes they are making and to put them on the right track. These interactions prevent students from feeling insignificant and anonymous and engage them in problem solving and critical thinking. This approach is time consuming and might not be used for each new concept, but it is an effective way to help students learn the fundamental ideas.

One of the reasons mathematics is considered difficult is because concepts are organized as a ladder, so missing steps makes learning impossible. Thus, it is important to make sure that the students learn every topic in a timely manner. Short diagnostic quizzes can be used to give feedback to students about their performance, to motivate them to study, and to help the instructor determine what concepts require extra-explanations. The role of these quizzes is mainly formative, and they can contribute little or nothing to the final grade. Since the initial mathematical background is important, the first diagnostic quiz can be administered during the first lecture to make the students aware about potential gaps in their knowledge. The rest of the quizzes are designed based on the main topics included in the course.

3. Results and discussion

Across six sections of an elementary calculus course, I evaluate student performance using the final percentage that determines the course grade. This percentage reflects a weighted combination of assignments (10%), two midterm examinations (25% each), and a final exam (40%). For three of these sections the teaching was lecturing, without any student involvement, and for the other 3 sections active lecturing was used, including classroom assessment techniques for rapid feedback, problem solving exercises and short diagnostic quizzes. In Table 1 I present the number of students in each of the six sections that obtained large percentage (80% or more), medium (between 55% and 79%) and small (less than 55%). To pass the course and use it as pre-requisite for higher level courses, 55% or more is needed.

Table 1. Number of students in each of the six sections that obtained large percentage (80% or more), medium (between 55% and 79%) and small (less than 55%).

Number of students	Student Centered Lecturing			Lecturing		
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
Large total %	8	11	11	6	6	8
Medium total %	18	19	19	8	15	13
Low total %	17	3	19	14	25	13
Total	43	33	49	28	46	34

The main topics covered by this course are limits, differentiation, and integration. According to the course objectives, upon completion of this course, the student will be able to

- Apply algebra to solve questions involving limits, differentiation and integration

- Calculate and use derivatives of algebraic and trigonometric functions, composites of these functions and functions defined implicitly
- Apply calculus to solve problems involving tangents, areas, optimization, related rates, curve sketching, linear approximations and rates of change
- Calculate derivatives and integrals of simple functions using definitions
- State and apply fundamental theorems such as the Intermediate Value Theorem, the Extreme Value Theorem, the Mean Value Theorem and the Fundamental Theorem of Calculus.

The students in sections 1-3 were given in class problem solving exercises and three 10 minutes long quizzes. Problem-solving exercises offer hands-on experience, and target concepts that students find difficult, or methods that are crucial for learning calculus. For example, after solving several examples, I ask the students to calculate the following limit, while I pass by and check their work:

$$\lim_{x \rightarrow 0} \frac{1 - \sqrt{1 - x}}{x^2 + 2x}$$

The role of the quizzes was to motivate the students to memorize trigonometric, differentiation and integration formulas, and to learn at least the basic techniques for graphing a function, calculating a derivative or an integral. Through the quizzes the students get timely personalized feedback, and I get information about the common mistakes and the concepts that the students find difficult.

I administer Quiz 1 in the second week, immediately after the review, to help students recognize weaknesses in their mathematical background before the course progresses. Quiz 1 tests the trigonometric formulas and it also includes a question like the one listed below:

Graph the function:

$$f(x) = \begin{cases} -2x + 4 & \text{if } x < 0 \\ 3 & \text{if } 0 \leq x \leq 2 \\ x^2 & \text{if } x > 2 \end{cases}$$

Quiz 2 is administered after I finish teaching differentiation of functions. Calculating derivatives is a fundamental topic of this course. The students are not able to learn the next topics about applications of derivative and about integration without first mastering differentiation of functions. This quiz reminds the students that it is essential to memorize and correctly apply differentiation formulas. Moreover, if the level of the class is not satisfactory, I can spend extra time covering this fundamental topic, and I also identify the students that struggle such that I can contact them and offer help. Quiz 2 tests the differentiation formulas and also contains a question similar to the one below:

Calculate the first derivative of the following function (do not do any simplifications)

$$f(x) = \frac{\sin^7(5x)}{x^2 + 3}$$

Quiz 3 cover integration. Since it is administrated before the last week of classes, it is the last test before the final exam. Usually students find integration more difficult than 3mportance3tion, especially integrals of trigonometric functions. Thus, in this quiz, in addition to integration formulas, I emphasize again the 3mportance of memorizing and applying trigonometric A sample problem from quiz 3 is included below:

Calculate

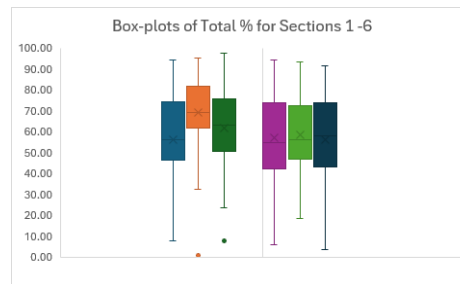
$$\int_{\frac{\pi}{6}}^{\frac{\pi}{4}} \frac{1 + \sin^2 x}{\sin^2 x} dx = \dots\dots$$

Figure 1 displays boxplots of the final percentages earned by students across the six sections of the calculus course. The three boxplots in the left side represent the sections where student-centered lecturing was used. We can notice that the 25% quartiles and the medians are slightly larger than for the three boxplots in the right side that represent the sections where no student involvement was used. However, there is a lot of overlapping in the boxplots, and this is shown also by the values of the means and standard deviations given in Table 2.

Table 2. Means and standard deviations of the final percentage for each section.

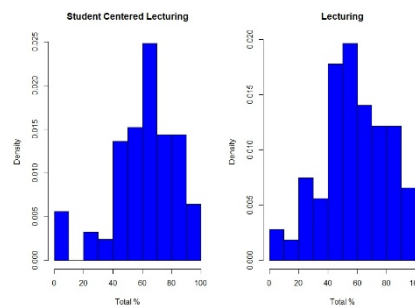
	Student Centered Lecturing			Lecturing		
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6
Mean	56.35	69.15	61.92	57.35	58.53	56.08
Standard Deviation	21.17	18.81	20.05	23.20	18.16	24.49
Overall mean	61.58			57.75		

Figure 1. Box-plots of total percentage obtained by students in sections 1-3, where students-centered lecturing was used (left side, blue, orange, dark green), and in sections 4-6 where lecturing was used (right side, purple, green, dark blue).



To examine whether student-centered lecturing leads to differences in the mean final percentage, the data are partitioned into two groups corresponding to sections 1–3 and sections 4–6. Figure 2 includes the histograms for the total percentages for the two groups. We apply the two-independent samples t-test with the hypotheses $H_0: \mu_{\text{Student centered}} = \mu_{\text{Lecturing}}$ and $H_a: \mu_{\text{Student centered}} \neq \mu_{\text{Lecturing}}$. The test statistics is $t = 1.3694$, and the p-value = $0.1723 > 5\%$, so we do not reject H_0 , and we conclude that we do not have enough evidence that the student centered strategies influence the mean of the final total percentage obtained by the students.

Figure 2. Histograms of the final percentages obtained for the students that benefited from the student centered lecturing (left) and of the final percentages obtained by the students in the sections where lecturing was used (right).



The boxplots in Figure 1 and the histograms in Figure 2 suggest a difference between the two groups in the number of students that obtain low final percentage. To test if there is any relationship between the number of students obtaining large, medium and low final percentages and the teaching strategy, we apply the Pearson's Chi-squared test to the two-way table given in Table 3. The hypotheses are:

H_0 : There is no relationship between the number of students obtaining large, medium and low final percentages and the teaching strategy,

H_a : The teaching strategy and the number of students obtaining large, medium and low final percentages are related.

The test statistics is $\chi^2 = 7.0019$, and the p-value = $0.03017 < 5\%$, so we reject H_0 and we conclude that teaching strategy and the number of students obtaining large, medium and low final percentages are related.

Table 3. Number of students that obtained large percentage (80% or more), medium (between 55% and 79%) and small (less than 55%).

Number of students	Student Centered Lecturing	Lecturing
Large total %	30	20
Medium total %	56	36
Low total %	39	52

Next, we test to see which proportions are different from the three categories of final percentages: large, medium and low. Table 4 contains the results of the three tests. Here $\pi_{\text{Large, Student centered}}$ denotes the proportion of students that obtain large final percentages when student centered lecturing is used and $\pi_{\text{Large, Lecturing}}$ denotes the proportion of student that obtain large final percentages when lecturing is used, and similarly for medium and low final percentage. Since we are doing multiple comparisons, we apply the Bonferroni correction, and we calculate also the adjusted P-values.

Table 4. Test results.

Hypotheses	χ^2 Test statistics	P-value	Adjusted P-value
H ₀ : $\pi_{\text{Large, Student centered}} = \pi_{\text{Large, Lecturing}}$ H _a : $\pi_{\text{Large, Student centered}} \neq \pi_{\text{Large, Lecturing}}$	0.40107	0.5265	1.00000000
H ₀ : $\pi_{\text{Medium, Student centered}} = \pi_{\text{Medium, Lecturing}}$ H _a : $\pi_{\text{Medium, Student centered}} \neq \pi_{\text{Medium, Lecturing}}$	1.7298	0.1884	0.56531191
H ₀ : $\pi_{\text{Low, Student centered}} = \pi_{\text{Low, Lecturing}}$ H _a : $\pi_{\text{Low, Student centered}} \neq \pi_{\text{Low, Lecturing}}$	8.345	0.003867	0.01160222

We reject the null hypothesis only for low final percentage, so we conclude that there is not enough evidence that the proportions of students that obtain large final percentages or the proportions of students that obtain medium final percentages are different for the two teaching strategies. However, we have evidence that the proportion of students that obtain low final percentages is smaller when student centred lecturing is used and a 95% confidence interval for the difference is $-0.33323042 < \pi_{\text{Low, Student centered}} - \pi_{\text{Low, Lecturing}} < -0.06237743$.

4. Conclusions

Echoing previous findings that classroom assessment techniques do not necessarily raise overall course grades (Cottell and Harwood, 1998), this study also finds no significant difference in mean final percentages across lecturing styles. What does change, however, is the failure rate: student-centered lecturing significantly reduces the proportion of students who fail. The additional communication and structured opportunities for students to monitor their own learning seem to offer the greatest support to those who are academically vulnerable.

Taken together, these results suggest that the primary impact of student-centered lecturing is not to raise overall performance but to provide critical support for students who might otherwise struggle. This pattern aligns with the idea that frequent feedback, opportunities for low-stakes assessment, and increased instructor–student interaction help students adjust their study strategies before high-stakes evaluations.

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