

1 Context

Technical communication skills are essential in both industry and academia, but are rarely addressed as an explicit part of the curriculum. Our goal with this project is to teach and enhance those skills in our students. When communicating to a technical audience, our goal is that student writing clearly demonstrates competency with the material and conveys understanding. This includes accurate use of terminology, clear definitions and explanations, but also soft skills such as the ability to anticipate points of confusion, creating diagrams to assist in demonstration, and to assess what information is unnecessary to provide a complete and satisfactory explanation.

MAT133Y5 and MAT223H5 were chosen as pilot courses for this intervention. MAT133Y5 is a service course offered by the department of Mathematical and Computational Sciences (MCS) to Economics and Management. It is taken primarily by students aiming to study commerce, though management and economics students take it as well. MAT223H5 is a core course in the MCS department, and is required in every major and specialist program. It is also a required course for students in the Economics specialist program. While listed as a 200-level course, it is often taken in first year.

2 Methodology

The nature of the intervention consists of two parts:

1. The funding of a centralized “Lead Writing Teaching Assistant” (LWTA), a senior student with a strong grasp of both mathematics and mathematics writing. The LWTA is responsible for training other TAs in assessing student writing, as well as consulting with instructors in the creation of writing based assignments. This year, the LWTA also assisted in assessing the effect of the program.
2. The continuation of writing assignments in MAT133Y5 and MAT223H5. These writing model the Peer-Assisted Reflection (PAR) method of instruction. Specifically, the PAR method consists of five steps:
 - (a) Students are provided with a problem which they will submit for marking and are asked to draft a solution to that problem. The first draft is written outside of classroom time. The audience for this problem consists of other students from the course, and indeed the draft will be read by another student shortly.
 - (b) Students are asked to reflect on their own work shortly after writing their draft. We provide several simple and concrete checkpoints that a student should verify have been included (defining variables, including explanations, showing work, etc), followed by

softer skills on which the student can reflect (accuracy, clarity, reasonableness of the solution, etc).

- (c) Students will provide feedback on each other's papers as follows:
 - i. Lectures which precede the deadline for a PAR assignment will begin with a 10 minute "training" session, where sample solutions are projected to the front of the room. As a class, we discuss potential feedback, and what types of feedback are valuable.
 - ii. Students pair up (randomly), exchange solutions with one another, and are given 5 minutes to provide written feedback. At this stage, there is no discussion between students.
 - iii. Each student is then given 5 minutes to explain their feedback to the other student (hence 10 minutes is required for this portion).
- (d) On their own time, students use the feedback provided to revise their draft solution into a final solution.
- (e) Students submit their final solution for marking.

Traditionally, this is done *during lecture* and students are paired with one another based on seating arrangement. MAT133Y5Y was taught entirely online this year – as well as in the prior year – and so we diverged from the traditional approach. Rather, students were given one week to complete the assignment in the absence of any other commitments. Randomization was performed using a python script, and emails were distributed indicating partners.

As mentioned in the 2020-2021 report, we had been playing around with the idea of offering partners heterogeneous assignments to see if there was a difference in student outcomes versus having the students work on the same assignment. Analysis can be found in Section 3.1. Last year's report also lamented the apparent compartmentalization of student writing to the writing assignments themselves. Consequently, this year we were much stricter in enforcing clarity of exposition as part of our grading rubrics in all assessments. This may have had some unintended consequences, as mentioned in Section 5.

All writing assignments and their solutions are included as a separate document.

3 Assessment

3.1 Objective

3.1.1 Writing assignment comparison

In collaboration with the Writing Specialist and funded by ISUP, the LTWA created a rubric by which to measure to effectiveness in overall writing. Four writing assignments were administered in MAT133Y5Y over the course of the 2021-2022 academic year. The first writing assignment was administered on September 25, 2021; while the fourth was administered on March 12, 2022. The LWTA randomly sampled the first and fourth writing assignments of fifty (50) students throughout the performance spectrum of students, distributed as follows:

	A students	B students	C students	D students
Number	10	15	15	10

The rubric examined the following points:

- sentence clarity,
- structure and logic,
- ambiguity of pronouns,
- level of reasoning explanation,
- and use of definitions.

Each category was weighted out of 4, and comparisons were to see whether students improved in each category. Data shows that 44/50 of the students improved in at least one category, and 38/50 improved in at least two categories. A half-dozen students however actually showed a negative score, but the TA prescribes this to fatigue. The report also included several salient recommendations, all of which I agree with and have included in Section 5. Moreover, towards the end of the year, we also noticed that a non-trivial number of students reported that their partner did not respond on Writing Assignment 4. At the moment, we do not have the technical access required to determine whether this was misrepresentation by the student (both partners indicating this despite it not being true), or if there were legitimately a large number of who failed to engage. That being said, 80 of 433 who completed the assignment indicated that their partner did not engage, while there were 556 students enrolled at the time. It seems likely that these are legitimate cases.

3.1.2 Heterogeneous assignments

Each writing assignment consisted of three different problems, labelled for example 1A, 1B, and 1C in the case of Writing Assignment 1. Students were divided into two groups based on the parity of their student numbers. Those with even student numbers were *both* assigned to do problem 1A and exchange with each other. Those with odd student numbers were paired off, and then each individual partner was assigned either 1B or 1C, but were always assigned different problems. The difference in learning achievement is summarized below. Amounts are given as “percentage difference of even students versus odd students,” wherein a positive number indicates that even students scored higher than odd students.

	Writing Assignments	Assignments	Tests	Exam
Difference	1.93%	1.27%	0.73 %	1.68%

While even students consistently performed better (none of these numbers are negative), these difference are not statistically significant.

3.2 Subjective

Feedback from teaching assistants and instructors was as follows:

- (133 instructor) Across the board solutions were better written than I would expect in a typical first year calc course, with the usual outliers on both ends (some were really well-written, some were the usual solutions with no words). I also found many students citing the theorem/result they used in their solution (“using substitution. . .”) even though sometimes it was the incorrect result (saying “using IBP” when they used substitution)
- (133 instructor) I definitely noticed some of the positive outliers. There were a number of solutions that were quite well-written, with an ideal balance of writing and mathematics. I feel like I noticed more solutions like this than is typical for a first year math exam.
- (133 instructor) Students’ communication skills were considerably better than those of an average first-year student and even better than some of the writing produced by the preservice teachers I taught at York. So, writing assignments were useful.
- (133 TA) I think the writing assignments were a bit confusing for the students, a lot of the just focused on writing a lot of words rather than actually organizing their thoughts. Maybe some sort of template or guideline could be given to the students on how they should organize their work better.
- (133 TA) I didn’t [mark the] WDI but from the assignments, I don’t think there was a notable increase in quality of writing and I think it may be partly related to students thinking that if they wrote out all the steps of their calculations, their thoughts could be relayed through that. Even at the end of the 2nd semester, there were some students who showed too little steps and/or didn’t communicate with words at all. A few students overshot in the other direction but that number was fairly small.
- (223 instructors) So, instructor feedback from marking the final exam this year is that a huge portion of the students not only struggled with conceptual questions/writing but just left such things blank or with barely coherent stubs. (On the other hand, there was a decent chunk that was producing really high quality writing.) The former group would struggle even on easy computational stuff they were supposed to largely teach themselves (messing up computing a basis for $\text{row}(A)$ for example). Definitely can’t say that W22 students’ writing was better. F21 is comparable to last year (when we ran the same type of assignments). But we don’t have any pre-covid baseline to compare to, so I’m not sure what more to say.
- (223 TA) I do think the positive is that all this focus on true/false, writing assignments, and reading is pushing students to develop proofs skills whether they like it or not. True and false forces you to connect concepts together. It’s hard to describe but I did see some more flexibility in the way students think about linear algebra now than before. I don’t know if they’re building the right vocabulary necessarily (I didn’t see any improvement in the way they describe their answers in the true and false on tests/assignments, like the communication style) but students seem more accepting of the fact that you have to properly justify your answers in math. I feel like honestly their writing in true/false on tests/assignments either stayed the same (mostly this) or decreased (because they’re memorizing theories and can’t use the words in the proper context maybe?) or maybe they’re just burnt out.

The issues in W22 are problems we didn't see in F21 to such an extent, and moving to in-person for the exam seems to be the big difference. I also suspect I didn't catch a large chunk of the cheaters that semester and last year (despite filing dozens of cases), so the difference from last semester to this one is tricky to assess.

The subjective feedback is mixed, and hard to parse. The 133 instructors – none of which have a stake in this project – feel that student solutions improved. However, the 133 TAs the volunteered responses report that they don't feel as though writing improved. It may be worth mentioning that both TAs were new this year, so their experience in marking was limited only to this class. The 223 instructors have generally reported that the Winter 2022 semester was all around abysmal. Student engagement and achievement were effectively non-existent, and this has made it difficult to assess how the writing assignments fared. However, Fall 2021 saw similar achievement to the previous year.

4 Lessons learned

1. In an effort to remedy the perceived compartmentalization that we observed last year, we ensured that clarity of exposition was a core component of the grading rubric in every single assessment this year. However, we may have oversteered in this direction. It is my personal observation that students were unusually verbose and overly detailed in their explanations this year. We largely attribute this to students erring on the side of caution and providing too much work.
2. Engagement towards the end of the course seemed to deteriorate, but there's some speculation that this may have been due to general fatigue. Per Section 2, 80 students reported that their partners did not respond on the final writing assessment of MAT133. On the surface, this would correspond to a nominal engagement of only 86%. Here we are only considering participation, and not whether this engagement was honest and substantial. However, 63 students failed to write the exam or even submit the majority of their assignments. While this is an unusually high number, it is not inconsistent with the previous online offering of this course. If we assume these students would not have participated in the writing assignment, it seems likely that we can narrow that 80 student number to closer to approximately 50 students (443 wrote the assignment of 493 who wrote the final exam). This puts engagement closer to 90%.

An interesting thought is that the more traditional version (in-lecture completion of the feedback component) might actually have less engagement by virtue of diminishing attendance experienced by in-person courses late in the year. This may be something to consider in future iterations.

3. We have tried to be careful in how much structure we give to students in their writing. In our experience, students cling to rigid structure, and writing should be fluid and flexible. Nonetheless, on the advice of the LWTA, it seems as though more attention to structure may be necessary. Despite our attempts to convey important points, such as defining variables, drawing diagrams, or explain the how and why of their work, students are still unaware of expectations. We have tried to consistently convey that a well written solution is concise,

providing enough detail to convince the reader of your argument without presenting excruciating detail. However, students seem fearful and tentative about “making a call” regarding what is an appropriate amount to write. Related to point (1) above, we believe they are defaulting to providing too much out of fear of losing marks, rather than exercise anything resembling judgement.

There are appropriate frameworks we could provide. For example,

- (a) Frame the question: Explain what you’re going to do and why.
- (b) Define appropriate variables and draw diagrams.
- (c) Carry through with the work, justifying where necessary.

A good solution need not be written like this, but perhaps we were too ambitious in our expectations. Students may need these figurative training wheels before they’re able to write adequately on their own.

4. TA feedback has been inconsistent and not always sufficiently detailed. In part, this is because we have been pulling from the normal course TAs to mark writing assignments. The TAs involved volunteer for the extra work, and while they receive training, having a stronger group of dedicated TAs that we could develop into skilled markers may make more sense. We have toyed with the idea of hiring the writing TAs “centrally” rather than at the course level. I now strongly believe that this is something we should pursue in future iterations.

5 Changes and amendments

1. Coordinatorship of MAT133 is being transferred from Dr. Holden to Dr. Yusun. Dr. Yusun would like to continue with the WDI grant. Dr. Holden will remain centrally involved with all administration, including (LW)TA hiring and training, as well as ensuring that the following changes are implemented, ensuring budgets are adhered to, and consulting with coordinators as necessary.
2. The creation of more structured writing assignments. In particular, the writing of the assignment will be broken down into stages:
 - (a) Describe your idea and how you will be solving the problem.
 - (b) Define all variables, draw diagrams as appropriate.
 - (c) Solve the problem, justifying your work in the process.
3. Creating a centralized team of writing TAs. So in particular, hiring TAs with the express purpose of marking writing assignments, rather than having WDI duties added onto existing contracts. This will allow us to dedicate more resources to training these TAs, and ensure consistency in TA feedback throughout both courses and across the range of writing assignments.
4. The transition to in-person teaching across all courses involved in the intervention means that implementation details will change. Peer feedback will be provided *in lecture* during class time, rather than relegated to student time outside of class.

6 Proposed budget for 2022-2023

There are a few notable changes to the proposed budget:

1. In creating a centralized team of dedicated writing TAs, we can economize training. However, the budget still includes a course-based breakdown of hours.
2. We would like the Lead Writing TA to still lead a training session for all course-based TAs in how to identify and mark good writing, so that we are consistently evaluating writing across all course assessments, and not just the writing assignments. We have identified this as “Course TA Training” under each course and in the LWTA’s budget.
3. This year we had significantly more students in MAT133 than usual. Our original formula was based on a 3:1 weighted average of initial and final enrollment. Based on these numbers from 2021-2022 (596 initial, 513 final), the number of MAT133 students is projected to be 575 students.
4. In practice, only about five TAs would mark any given assignment, so we have reduced the budget to take this into account in terms of marking and benchmarking. Note therefore that while the budget will say “5 TAs” for benchmarking, this is for the marking TAs and is different than “Course TA Training” which is training for the non-writing TAs.

MAT133Y5 PAR Assignments

Description	Hours	Cost (at \$50/hour)
Benchmarking Sessions	5 TAs \times 4 sessions \times 1 hours = 20 hours	\$1000
Marking PAR Assignments	5 mins/assignments \times 510 students \times 4 assignments = 190 hours	\$9500
	210 hours	\$10500

MAT223H5F PAR Assignments

Description	Hours	Cost (at \$50/hour)
Benchmarking Sessions	5 TAs \times 3 sessions \times 1 hours = 15 hours	\$750
Marking PAR Assignments	5 mins/assignments \times 485 students \times 3 assignments = 122 hours	\$6100
	137 hours	\$6850

MAT223H5S PAR Assignments

Description	Hours	Cost (at \$50/hour)
Benchmarking Sessions	5 TAs \times 3 sessions \times 1 hours = 15 hours	\$750
Marking PAR Assignments	5 mins/assignments \times 485 students \times 3 assignments = 122 hours	\$6100
	137 hours	\$6850

Lead Writing TA

Description	Hours	Cost (at \$50/hour)
Additional Training	8 hours	\$400
Benchmarking Sessions	1 hour \times 10 sessions = 10 hours	\$500
Development	10 assignments \times 2 hours = 20 hours	\$1000
Administration	10 assignments \times 2 hours = 20 hours	\$1000
	68 hours	\$3400

This yields a total of 552 hours at \$27600. At 1545 students, this corresponds to 0.36 hours (22 mins) per student, or \$17.86 per student.