END OF TERM REPORT: 18.100C

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The course 18.100C, "Analysis I," is a core undergraduate mathematics course, supplemented by the CIM flag (communication-intensive in the major). The purpose of the course is three-fold: to learn the same real analysis content as presented in the 100B course, to learn about successful mathematical writing and the use of LaTeX typesetting[1], and to learn about successful oral communication in mathematical science.

The course was organized with two 1.5 hour lectures and one 1 hour recitation per week. The lectures covered the core material, while the recitations covered writing, LaTeX, and some oral presentation. The course is worth 15 total credits, for which 3 are nominally granted to the recitation; however the students receive only one grade for this course. We therefore computed 20 percent of their end-of-term calculated grade from the recitation and 80 percent from the core material.

1. The three course components

In this section, we address briefly the effectiveness of the three components of this course (core material, writing, oral). The core material was lectured by H. Christianson, following closely the classic text of W. Rudin. The lectures, core homeworks, midterms, and final were all coordinated closely with two sections of 18.100B (lectured by R. Bezrukavnikov and R. Melrose). The syllabus used for 18.100B has been honed by many years of MIT history and experience, so we believe the overall content of the core material in 100C to be completely analogous to that in 100B. The effectiveness of running 18.100C concurrently with 18.100B is addressed in Section 3.

There were initially 30 students registered for the course, distributed between 2 recitations, taught by C. Desjardins, J. Lewis, and S. Ruff. After meeting with the instructors we determined that there was insufficient time for each student to give an in-depth oral presentation in addition to learning the writing skills we proposed in our initial syllabus. The course requirements include an oral component which we satisfied through several one-on-one instructor supervised peer-review sessions throughout the semester. We felt that this was the most efficient use of the available time and a good way to successfully fulfill the goals of the course. For future incarnations of this course, we strongly recommend a similar format for the following reason: students in the mathematics major at MIT have to take two CIM courses. History suggests the second CIM course is almost always a seminar course in which the students give oral presentations of at least 30 minutes. We therefore feel the emphasis in the recitation for 18.100C should be on writing and use of LaTeX.

[1]The LaTeX document preparation system is used almost universally by mathematicians, and is very popular among other scientific disciplines as well; this document was typeset with LaTeX. See `http://www.latex-project.org` for more information.

The LaTeX and writing component of the course was taught through a series of targeted exercises (see attached schedule matrix in Section 9), beginning with installation of the LaTeX packages and creation of simple documents. Subsequently, students were assigned a series of exercises to emphasize several different writing styles in mathematics, from writing homework solutions and test solutions, to writing for exposition and pedagogy, to writing for original research journals.

2. Online resources

There were several online resources available to the 18.100C students. We made use of a common website (hosted on math.mit.edu) for 100B and C with the core homework and solutions, as well as the Stellar capabilities provided by the MIT servers. The Stellar course management website was supposed to provide course content to the students, electronic homework submission, a forum, and gradebook services. While the potential for this is immense, the system is tied to the registrar's computer systems in a way which makes it very unstable with respect to student changes (drops, adds, etc.). The gradebooks have potentially lost grades of some students, although we of course had backups. Since any issues with the Stellar system must be resolved by contacting the registrar's office, it is very slow to fix any problems which might arise. We propose for future versions of this class and indeed for other classes that the Mathematics Department at MIT invest in a similar, internally managed system. This would allow more flexibility, and if the grade system were run on the Math department servers, our excellent IT staff can handle any problems that may arise.

3. Concurrence with 100B

As discussed previously, the core content of this course was taught concurrently with the 18.100B course. There were several goals in doing this. First, we wanted to ensure that any student taking 100C would get a comparable grade to what they would have received in 100B, provided they put in sufficient effort in the recitation component. Second, we wanted to make sure the pace and content of the core material in 100C was the same as 100B. Third, the core material for this course is very hard, and we wanted the students to have the option to attend more than one lecture on the same topics, or to sit in on a particular lecture if the lecturer's style was more to their preference.

We feel this did not create any unreasonable difficulties, and that the benefits far outweighed any problems we did encounter. If this model is used in future classes, the instructors need to be careful that additional problems from the recitation do not overlap with the exams.

4. Grading

One unfortunate consequence of the course credit distribution (80 percent core material, 20 percent recitation) is that the students only receive one grade for both the lecture and for the recitation. We believe that most students took the recitation very seriously and wanted to get as much out of it as possible simply because they are mathematics majors. However, the possibility exists for students to get an A in the course without putting much effort into the recitation, and some students may be tempted to abuse this situation. One possible solution is a system in which

transcript grades reflect both the recitation grade and the overall grade, so that the recitation grade is not completely diluted.

5. Assessment of necessary staffing

The course this semester was staffed by one lecturer for the core material, two TAs for the recitation (C. Desjardins and J. Lewis), and a TA from Writing Across the Curriculum (S. Ruff). The homework assignments in the core material were graded by an undergraduate grader independently of the grading for the recitation. The additional homework assignments for the recitation were graded by the TAs.

We estimate the TAs spent a total of 125 hours grading during the semester in addition to recitation preparation, the recitation period, and office hours. (This includes time spent by S. Ruff; see Section 8 for more on this.) Some students do drop the course, so the enrollment at the end will be smaller than in the beginning. It may be tempting to then hire only one TA and have only one recitation. We feel this is possible, provided much care is taken in choosing graders. Specifically, we have three possibile scenarios for staffing the class (in addition to the TA from Writing Across the Curriculum).

(1) The lecturer teaches the recitation (requires an extra semester-hour for the lecturer). In addition to an undergraduate grader for the core assignments, a talented graduate student grader or very talented undergraduate grader (a 100C student nominated by TAs from the previous term) is necessary. The second grader will be responsible for approximately 80 hours per semester. Since the homework for the recitations consists in great part of writing, the lecturer will have some necessary supervision to make sure it is graded appropriately. We estimate this will take approximately 20 hours of additional work per semester for the lecturer.
(2) Two graduate students teach the recitations and grade the additional homework assignments. This is the model described in this report.
(3) One graduate student teaches the recitation and an additional grader is necessary as described in the first model.

In scenarios 1 and 3, the TA from Writing Across the Curriculum can help the graders by providing targeted grading suggestions. We feel for these scenarios, this is probably the best use of time for this TA.

We remark that if more oral component is deemed necessary for future versions of this course, then only the first and second model are feasible, as otherwise there is simply not sufficient class time in the semester for substantial oral presentations from every student.

An additional, more extreme scenario is to turn the recitation into an independently listed "writing lab":

(4) The course listing for 100C is eliminated entirely. Students register for 100B and a coordinated lab worth 6 credits. The lab is taught as an autonomous class either by senior faculty or talented graduate students. The additional credit assignment is commensurate with the amount of work both the students and the TAs actually did for the recitation in 100C.

In any case, a dedicated weekly meeting with all staff members is necessary in order to coordinate plans for future recitations, grading, etc.

6. Specific recitation activities and assignments

Recitation activities fell into three main categories: skill tutorials, peer reviews, and miscellanious activities. In this section, we describe these three types of class periods and their significance to the course goals. For a list of all recitation activities by week, see Section 9.

In a skill tutorial, students typically enter the room to find an introductory question (for example, "How would you explain the Intermediate Value Theorem to your 5-year-old niece at Thanksgiving? to a job interviewer? to your roommate the chemistry major?"), sometimes accompanied by a brief handout. The TA ensures that students sit in pairs or small groups and discuss the question or handout for a few minutes. Afterwards, the TA moves discussion to the front of the room, where a technique or skill relevant to the opening discussion (for example, assessing audience sophistication and communicating for a nontechnical audience) is introduced and discussed.

Assigned work following a skill tutorial reinforces and practices the skill.

In a peer review, students arrive in class having previously submitted some writing assignment. TAs arrange students into pairs or small groups in such a way that paired students have written on *different* topics. Students then exchange papers and provide written and oral comments to each other, while TAs oversee this process and keep it on track. (In some cases, submissions were a few days in advance of the recitation and students were paired up and had the opportunity to read over their partner's paper in advance of recitation.)

Note that the first peer review should begin with instruction in high-quality peer reviewing. This semester, we ran a brief role-playing exercise using all three TAs to demonstrate how to (and how not to) give substantive, constructive criticism while avoiding insulting comments, as well as how to be a good recipient of peer review.

Assigned work following a peer review is to revise the submitted assignment. In addition, the students submit scanned copies of the written portion of their peer review, which are graded for comprehensiveness and quality. During weeks of peer review, we strongly suggest that TAs *not* also grade the submitted assignments. In our experience, this led to students ignoring the peer review in favor of instructor comments. This should also help moderate the grading load on instructors.

Miscellaneous recitation activites took place on weeks when no recitation homework was assigned. They are included in the table in Section 9.

7. Writing assignments and LaTeX

One of the important skills associated with writing mathematics is the use of LaTeX. All recitation assignments were written in LaTeX and submitted via Stellar. We felt that learning to use LaTeX is best accomplished by doing rather than seeing. Accordingly, only brief instruction was given during the recitation hour on how to write successful LaTeX generated documents. Instead, a series of assignments were given early in the semester which gradually exposed the students to more complex environments and constructions. Inasmuch as the students are now skilled users of LaTeX, we believe this approach was successful while requiring minimal use of the limited time in recitations and without an unnecessarily heavy workload for the students.

In the future, we recommend that a few minutes of recitation be devoted to student questions about LaTeX, at least in the beginning of the semester, and that TAs carefully assess how long students are spending to type their work in LaTeX.

For future versions of this class, and especially if the third model described in Section 5 is adopted, we suggest fewer assignments with more pages to help lighten the load and responsibility for the graders. For example, rather than having three assignments each submitted twice, we suggest two assignments each submitted three times.

8. Writing Across the Curriculum

The overall organizational help, suggested course activities, and especially the brief targeted lectures on very specific writing topics have been extremely valuable to the course. S. Ruff was stretched over multiple courses this semester, but for future courses the lecturer and TAs will benefit from as much time and assistance as possible from the Writing Across the Curriculum office. If the one-TA model is adopted for future courses, the TA from Writing Across the Curriculum can certainly be of great help with brief guided suggestions for the graders without actually having to do any of the grading. In any staffing model, we believe that having the TA from Writing Across the Curriculum lead the other TAs and/or graders through the grading of two or three student papers after each writing assignment is necessary (as graduate students in mathematics typically are not trained in many of the writing skills that this class is meant to impart) but that also having the TA from Writing Across the Curriculum independently grade papers is probably unnecessary. (S. Ruff estimates that she spent 45 hours this semester grading student papers, and we believe that this was an unnecessarily large use of her time.)

9. Table of recitations

The table below contains a summary of our schedule and lesson plans, homework, as well as the purpose or goal of each.

Week	Tutorial	Homework	Purpose
1	Intro Q: Are there gaps in the rationals? 40min: discuss paradox of there are (not) gaps in rationals–get students involved in figuring out how both are possible and in formalizing what's going on; 10 min: writing LaTeX, hand out syllabus, field Qs.	In LaTeX, write up "yes" and "no" arguments	Translating mathematical concepts into clear mathematical language.
2	Exercises in working with formal logic statements, natural language statements, negations and quantifiers	Worksheet on translating between natural language and logic notation. Included making a table in LaTeX	Translating between mathematical concepts, mathematical language, and logic notation.
3	Information order and connectivity; guiding text	Revision of first writing assignment	Learn how to help the reader understand text
4	Strategies for proof writing	Formulate precise questions to have answered for test preparation	Strategies for proof writing: mathematical rhetoric and writing to learn
5	Pair discussion: try to answer each other's questions. If you can't, then refine the questions—what specifically do you not understand?	Short write-up including the inclusion of a figure in LaTeX	Formulating precise questions; exam prep
6		Write a technical report on one of four suggested topics relevant to the course material	When to write conceptually vs formally
7	Skit demonstrating good and bad peer review. Supervised practice reading each other's papers	Peer review	recognize that in future they'll learn most from their peers: giving & receiving peer review & finding good partners are important skills; analyze/discuss good/bad writing; when to choose delta
8	Full peer review, including discussion of comments written on each others papers for homework the previous week	Revision of second writing assignment	Peer review & multiple quantifiers
9	How to use LaTeX efficiently; The difference between propositions, theorems, etc.; Using auxiliary functions in proofs.	None: Test	Strategies for proof writing: structure and elegance
10	How would you explain your mathematical work to different audiences? Responding to the needs and sophistication level of the audience.	Choose a theorem from class and explain it to three different audiences of your choosing.	Writing for different audiences
11	Peer review	Revise third writing assignment based on peer review	Improve writing
12	Review and discuss research on communication skills needed in a technical field. Read and discuss case study of email "flame war"	None: Thanksgiving.	Communicating professionally
13	LyX; Beamer, presentation materials; BibTeX; xfig		Advanced tools for mathematical communication