Department Name: Mathematical Sciences (Mathematics and Statistics in 2020-21)
WEC Liaison Name: Julianna Tymoczko
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WEC Liaison phone: 734-646-3521
Department Chair Name: Luca Capogna
Date of Writing Plan Submission: 11/8/2021

Please list the number within the department of the following:
Professors: 4 (Fall 2021)
Associate Professors: 2 (Fall 2021)
Assistant Professors: 2 (Fall 2021)
Additional (Interim Faculty, Adjunct Faculty, Instructors, etc.): 3 full-time plus 3 individual courses (Fall 2021)

Majors:
Total number of students enrolled in major (as of Spring/2021): 77, plus 8 postbaccs and 6 minors
Total number of students graduating with major (as of Spring/2021): 29, plus 8 postbaccs and 5 minors

WEC Process:

<table>
<thead>
<tr>
<th>WEC Meeting</th>
<th>Date held</th>
<th>#participated/ #invited</th>
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<tbody>
<tr>
<td>WEC Meeting 1</td>
<td>10/21/2020</td>
<td>9/13</td>
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<tr>
<td>WEC Meeting 2</td>
<td>12/8/2020</td>
<td>9/13</td>
</tr>
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<td>WEC Meeting 3</td>
<td>3/17/2021</td>
<td>8/13</td>
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<tr>
<td>WEC Meeting 4</td>
<td>4/28/2021</td>
<td>7/13</td>
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Signature Page

WEC faculty liaison:
Print Name: Julianna Tymoczko
Title: Professor
Signature/Date: 11/08/2021

Department Chair:
Print Name: Luca Capogna
Title: Professor, Chair
Signature/Date: 11/08/2021

Chair, Committee on Writing and Public Discourse:
Print Name:
Title:
Signature/Date:
Introductory Summary:

Briefly describe the reason(s) why this department became involved in the WEC program, key findings that resulted from the process, and the implementation activities that are proposed in this Writing Plan. (1/2 page maximum)

MTH has a longstanding interest in developing writing and presentation skills and a tradition of pedagogical experimentation to support communication, understood broadly. Historically, specific classes have had particular emphasis on writing, including 281 and 153 (though see below for more on 153). In the past few years, individual faculty and teams of faculty have piloted diverse writing initiatives across various other levels of the curriculum (including the introductory sequence 111/112 and a 300-level Calderwood seminar). Right now, we find ourselves in a period of faculty turnover that made this an auspicious moment to take a bird’s-eye view of the curriculum as a whole and how writing fits into the curriculum.

Our main findings are:

● There are particular aspects of writing instruction where students and faculty perceptions do not align and that we would like to understand better. We may have identified a possible gap in writing instruction through mid-level courses; alternatively, this may be an area where we need to better explain and contextualize writing instruction in mid-level courses (e.g. perhaps students see 200-level courses as focusing on proof-writing in contrast to communication).

● MTH 153 has been a cornerstone of writing for the majors, but has also lacked consistency of goal or instruction over the last few years. More clarity about the goals and techniques in MTH 153 could be warranted.

● When analyzing curricular flow through the department, it became clear that we needed to better ensure that it is not possible to skip writing instruction. We need to assess how students on different pathways through the major experience writing. For instance, do we emphasize certain skills in introductory classes and then expect them to be considerably developed without having in fact scaffolded students repeatedly throughout the intermediate courses?

● Many of us valued discussions about rubrics and grading more generally, and felt that these issues merit recurring conversations. We shared the goals of being fair and inclusive in our grading, and at the same time communicating to students about their learning progress. We recognized particular challenges around:
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Writing Plan Narrative

- Responding effectively to international students and our linguistically diverse community
- Recognizing and avoiding grading mechanisms that perpetuate gatekeeping or that punish rather than encourage student learning

- Many of us felt we haven’t had conversations about writing, either instruction of writing or the qualities of good writing, especially in a mathematical context. We were curious about assignments that worked well in others’ math classes. Many of us were interested in receiving explicit guidance on how to teach writing effectively, especially in courses that also have content requirements and need to reach a diverse audience of students.
- We discussed creativity in math (and in general) and agreed this is a key ability that we want to nurture. Many of us also agreed that creativity feels particularly hard to teach.

These findings lead naturally to the activities proposed in the next year.

Section 1: DISCIPLINE-SPECIFIC WRITING CHARACTERISTICS
What characterizes academic and professional communication in this discipline?

There was broad agreement among the faculty at our first WEC meeting that strong writing in the mathematical sciences has the following characteristics:

- **Creative.** Mathematical writing is at its heart creative. This creativity appears in many aspects of mathematical writing, including the development of new results and ideas; the process of generating and asking questions; the calculations and large-scale computational work to generate data and test hypotheses; and exposition itself.

- **Clear and concise.** Sometimes concision works in the service of clarity. Other times, adding explanations further clarifies our writing. Most mathematical writing aims to include all necessary information without any extra information. Professional writing seamlessly integrates technical mathematics with words and images based on which is clearest and most concise.

- **Logical.** Deductive reasoning holds a special place in the mathematical sciences as well as in mathematical writing. At the micro scale, logic is the heart of the traditional mathematical proof (though not all mathematical writing contains proof). At the macro scale, information in mathematical writing is presented in a logical fashion; different sections of the text are organized to produce a systematic flow of information.

- **Contextual.** Mathematical writing contextualizes ideas using graphics, tables, figures, and/or data. It connects different results, both in order to build acrretively on previous
work and to explain how different theorems, models, and algorithms fit together or complement each other. It communicates with metaphors and imagery as needed. Good mathematical writing is also aimed at its audience: the context it provides incorporates the background, interests, and level of the anticipated readers.

Section 2: DESIRED WRITING ABILITIES

*With which writing abilities should students in this department’s majors graduate?*

We developed the following list of writing abilities with which we would like our majors to graduate.

1. Demonstrates facility with technical writing (including for proofs and calculations) by
   a. giving supporting evidence for a proof or calculation using other mathematical results;
   b. using graphs and data to support or illuminate their arguments;
   c. using math symbols and terminology appropriately, including set and functional notation;
   d. managing longer text with paragraph breaks, formatting, figures, etc;
   e. conveying mathematical ideas in complete, grammatical sentences; and
   f. using bibliography/citations/cross-references appropriately.

2. Uses deductive reasoning by
   a. showing how they solved problems using deductive logic; and
   b. making proper use of logic and quantifiers and appropriately using theorems and definitions in their writing.

3. Writes clearly and coherently by
   a. writing concisely; and
   b. communicating intuition, isolating a central idea and presenting it simply;

4. Develops creativity by
   a. asking questions and posing conjectures or proof approaches;
   b. solving problems in multiple ways; and
   c. varying or generalizing hypotheses, conditions, and attributes.

5. Writes in their own style and appreciates their own communication skills and style.

6. Contextualizes mathematical ideas by synthesizing different ideas from various sources and reading a definition/theorem, applying, and interpreting as part of the problem-solving process.

7. Demonstrates audience awareness by writing with other people effectively and collaboratively; appreciating differences in writing genres, purposes (including writing for presentations), individual styles, levels of formality, etc.; and building a narrative,
persuading the reader of the value of the work.

Section 3: INTEGRATION OF WRITING INTO DEPARTMENTAL CURRICULUM
How is writing instruction currently positioned in this department’s curriculum? What, if any, course sequencing issues impede an intentional integration of relevant, developmentally appropriate writing instruction?

In our meetings, the faculty agreed in broad terms about what the introductory, mid-level, and advanced courses should provide in terms of writing instruction, as sketched below. However, the WEC survey identified a mismatch between student and faculty perspective, which is described in more detail at the end of this section.

Introductory courses: The introductory calculus classes (MTH 111/112) put significant emphasis on communication of mathematics rather than just performative mathematics. MTH 153 is supposed to introduce proofs while also introducing a range of content for computer science majors; our WEC discussions led many of us to conclude that the course has not been consistently doing this recently (possibly neither the writing aspect nor the full range of expected content!). MTH 211 and 212 do not traditionally have the same emphasis on writing, especially if taught by temporary faculty. We did not collectively find that bringing more writing instruction into 211/212 is a priority, especially given what we articulated about 153.

Mid-level courses: The role of writing in mid-level courses is traditionally more variable, and we generally felt this was warranted given the range of goals in mid-level instruction. Majors must pass through at least one of four courses: MTH 233, 238, 280, 281. MTH 281 is heavily focused on proof writing and (oral) presentations of mathematics. MTH 233 also traditionally focuses on proof writing, but has had rotating staffing in the last few years, which may interfere with this in practice. MTH 238 and 280 traditionally teach less abstract material but still contain considerable emphasis on proofs and in recent years have generally been taught by longterm faculty. The other mid-level courses (246, 254, 255, 264, 270) are electives and have different levels of instruction; we are generally comfortable with this, though note that students focusing on mathematical statistics may end up with less writing instruction through MTH.

Advanced courses: 300-level courses are topics courses and can vary dramatically. Most have some sort of larger written project incorporated towards the end, though some do not. Applied 300-level courses often have more computational work in which writing resembles lab reports more than papers.

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Faculty/student perceptions of writing in the department: The student survey reported confusion about the role of writing in the middle of their major, and some felt that writing is simply introduced from thin air towards the end. This does not agree with the faculty perspective. From the faculty perspective, writing is treated seriously throughout the curriculum, though staffing turnover has disrupted some of our traditional sequencing.

Hypotheses: We considered various hypotheses: that there actually is a writing gap at the mid-level, and 200-level courses don’t adequately bridge the distance between 100-level and 300-level; that students simply don’t recognize the writing we do in 200-level courses as writing, in which case there’s a communication or messaging lapse that instructors need to correct; that students are perceiving proof-writing as a narrower skill than the writing they do in MTH 111/112 or in 300-level courses. We need to gain more clarity on this issue.

We also wondered whether different pathways through the major could leave some students with very little writing exposure, or very little writing exposure until a high-level course (with concomitant high-level expectations). This is further addressed in Section 6.

Section 4: ASSESSMENT OF STUDENT WRITING

What concerns, if any, have unit faculty and undergraduate students voiced about grading practices?

Please include a menu of criteria extrapolated from the list of Desired Writing Abilities provided in Section 2 of this plan. (This menu can be offered to faculty/instructors for selective adaptation and will function as a starting point in the WEC’s longitudinal rating process).

The faculty developed a provisional grading rubric and plan (see below). We anticipate a cycle of revisions to the rubric as we learn from the results of student assessments as well as the assessment process itself.

In addition, faculty felt unclear on how the grading rubric was or should be used. Faculty unanimously opposed the idea that the rubric be a mandate or a constraint. A number of faculty voiced concerns about equity, and concomitantly about preserving creativity, and about encouraging rather than squashing our students. Some faculty have been experimenting with practices like ungrading and wanted to consider how to incorporate feedback, reflection, and motivation without punitive or discouraging assessments. There was widespread desire for a faculty discussion group on rubric formation as part of our implementation ideas (see Section 5).
Grading Criteria, as developed by the faculty:

1. Demonstrates facility with technical writing (including for proofs and calculations) by
   a. giving supporting evidence for a proof or calculation using other mathematical results. **CRITERION:**
      i. Supports a proof or calculations with mathematical results at a level of detail as established in the course
   b. using graphs and data to support or illuminate their arguments **CRITERIA:**
      i. Supports/illummates arguments with graphs and data that address the argument
      ii. Chooses axes/endpoints/scale that highlight key features
      iii. Where appropriate, uses schematics or other visualizations to convey the intuitive ideas behind notation
   c. using math symbols and terminology appropriately, including set and functional notation **CRITERIA:**
      i. Follows established conventions for set and functional notation as defined in course
      ii. Correctly distinguishes among mathematical objects (e.g. sets versus cardinalities)
      iii. Defines notation before using
      iv. Balances notation with verbal descriptions
   d. managing longer text with paragraph breaks, formatting, figures, etc. **CRITERION:**
      i. Uses paragraph breaks, formatting, figures, sections, and other devices to break text into readable piece
   e. conveying mathematical ideas in complete, grammatical sentences **CRITERIA:**
      i. Uses complete sentences
      ii. Uses correct grammar and punctuation, where mathematical notation makes contextual sense (e.g. when read aloud)
   f. using bibliography/citations/cross-references appropriately **CRITERIA:**
      i. Includes bibliographical information using the formatting recommended by the instructor (MLA, Chicago Manual of Style)
      ii. Cites relevant theorems or sections using the formatting recommended/required by the instructor

2. Uses deductive reasoning by
   a. showing how they solved problems using deductive logic **CRITERION:**
      i. Moves from hypothesis to conclusion using steps that are explicitly and sequentially described
   b. making proper use of logic and quantifiers and appropriately using theorems and definitions in their writing **CRITERIA:**
      i. Appropriately uses conditionals, if-and-only-if, exclusive and inclusive or,
other logical components of an argument, and identifying if hypotheses are met when using a theorem
ii. Explicitly identifies when hypotheses are met when using a theorem.
iii. Explicitly states/uses the conclusion of a theorem.

3. Writes clearly and coherently by
   a. writing concisely CRITERIA:
      i. Uses repetition sparingly and with intention (e.g. for rhetorical effect or to provide multiple solutions to a problem)
      ii. Uses auxiliary verbs and passive voice knowingly, with an awareness of their pitfalls
      iii. Clearly emphasizes main points in topic sentences
   
   b. communicating intuition, isolating a central idea and presenting it simply
   CRITERIA:
      i. Summarizes the main ideas in the argument, either standalone or interspersed throughout the text, as warranted by the complexity of the argument
      ii. Uses schematics, graphics, metaphors, examples, and other tools to express the core ideas of an argument

4. Develops creativity by
   a. asking questions and posing conjectures or proof approaches CRITERIA:
      i. Contains questions and conjectures, which could include a possible extension of a result from class, a pattern based on evidence/examples,
      ii. Sketches an incomplete proof
   b. solving problems in multiple ways CRITERION:
      i. Provides multiple solutions using different approaches, e.g. algebraic, geometric, using a model, using approximations.
   c. varying or generalizing hypotheses, conditions, and attributes CRITERION:
      i. Identifies where and how changing properties or hypotheses would affect an argument or result

5. Writes in their own style and appreciates their own communication skills and style CRITERION:
   i. Displays a clear and consistent voice

6. Contextualizes mathematical ideas synthesizing different ideas from various sources and reading a definition/theorem, applying, and interpreting as part of the problem-solving process CRITERIA:
   i. Identifies connections between ideas from texts, collaborators, and courses.
   ii. Relies on multiple theorems, definitions, tools, or strategies
   iii. Confirms that hypotheses hold prior to using theorems, definitions, and other results
   iv. Correctly links implications and properties from theorems, definitions, and other results

7. Demonstrates audience awareness by writing with other people effectively &
collaboratively; appreciating differences in writing genres, purposes (including writing for presentations), individual styles, levels of formality, etc.; and building a narrative, persuading the reader of the value of the work **CRITERIA:**

1. For collaborative writing: merges pieces from multiple contributors to form a unified whole
2. Identifies a consistent target audience and goal, either implicitly or explicitly
3. Uses technical notation, level of formality, and genre consistent with the target audience and goal
4. Uses signposts to link different parts of the argument
5. Uses remarks, examples, figures, and other devices to illustrate applications or aesthetic value of the result

Section 5: SUMMARY OF IMPLEMENTATION PLANS, including REQUESTED SUPPORT

*What does the department plan to implement during the period covered by this plan? What forms of instructional support does this unit request to help implement proposed changes? What are the expected outcomes of named support?*

The initiatives for which we had most faculty interest are the following:

- Form a group to track different pathways through the major and ensure that all contain sufficient explicit writing instruction.

  The department just received approval for a new mathematical statistics major housed jointly in MTH and SDS, so this is an excellent moment to ensure that flow through the current pathways in the major guarantee writing instruction. We plan to form a subcommittee of interested faculty members to meet once or twice before spring semester to analyze the pathways and identify any gaps. The committee will consult with SDS about the mathematical statistics major so that students in this pathway receive appropriate writing instruction for both mathematical and statistical contexts.

- Develop a list of writing skills and content that faculty are expected to cover in MTH 153

  Three faculty have already started this process (the faculty who taught MTH 153 in 2021). Our current plan is to develop a shared collection of materials and structures that worked well, including:

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Smith College Writing-Enriched Curriculum
Writing Plan Narrative

- Lists of topics and proof techniques that students should be capable of using
- Textbook
- Rough (weekly) schedule of readings and topics
- Problems for proof practice
- WebWork and other computational problems for student practice
- Suggestions and pros/cons of different grading practices

We have preliminary materials, and plan to meet at least once at the end of the semester or during interterm to compare experiences and summarize suggestions for future instructors. At that point, we plan to distribute these materials to the whole department to invite feedback.

Depending on the feedback, we may ask for assistance from the Jacobson Center in further implementation.

- Faculty discussion group on rubric formation, facilitated by the Jacobson Center

We would like the Jacobson Center to facilitate discussion on rubric formation and use. We hope to incorporate feedback from the team that assessed student writing samples. We anticipate that this will be part of a semi-regular series of discussions (once per year or per semester) to guide evolving practices.

In addition, the following initiatives all had significant interest but not a critical mass of willing participants. We plan to revisit these initiatives during interterm and again at the end of spring semester of 2022 to see whether the number and/or availability of interested faculty has increased. In addition, we anticipate that implementing earlier initiatives may shed light on and/or prompt revisions of some of the following.

- Significant interest in a group of faculty studying the course/skills matrix for gaps in explicit writing instruction
- Significant interest in talks on creativity in mathematics but disagreement about preferred format (e.g. discussion group to brainstorm ideas, workshop on incorporating creativity into assignments, outside speaker)
- Significant interest in some form of assignment-sharing but disagreement about preferred format
- Significant interest in some form of initiatives around diversity and inclusion in teaching and grading but disagreement about preferred format

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Section 6: PROCESS USED TO CREATE THIS WRITING PLAN

How, and to what degree, were a substantial number of stakeholders in this unit (faculty members, instructors, affiliates, students, others) engaged in providing, revising, and approving the content of this Writing Plan?

All faculty, lecturers, and current instructors were invited to each WEC meeting, for a total of 13 invitees (including an emerita faculty who declined to participate). Actual participation at M1, M2, M3, and M4 was 9, 9, 8, 7, respectively. Each invitee attended at least one meeting, except the emerita and one associate professor. Each meeting had participation from key stakeholders across the department (including teaching-focused, research-focused, and temporary or part-time instructors).

Attendees were generally very active, engaged, and passionate about the topic. Participants provided thoughtful and constructive feedback on written materials during meetings and spent considerable effort producing the spreadsheet of courses taught in the department.

The final version of our Writing Plan was assembled post-deadline in the fall and received no meaningful feedback from faculty prior to submission (it has been sent to them concurrently for feedback).