I. Cover Page

Please fill in the gray areas on this form.

Date: 10 October 2019

2nd Edition Writing Plan: Fall 2019
1st Edition submitted: Fall 2018

School of Mathematics

WEC Unit Name
Mathematics

Department

Craig Westerland

WEC Faculty Liaison (print name)
cwesterl@umn.edu

Email

Science and Engineering

College

Associate Professor

Title

612-625-0523

Phone

Writing Plan ratified by faculty

Note: This section needs to be completed regardless of Writing Plan edition.

Date 11 October 2019
If Vote: /

Process by which Writing Plan was ratified within unit (vote, consensus, other- please explain):
The Writing Plan was ratified by consent. Specifically, it was sent to regular and contract faculty members for a period of 5 days for comment and for them to indicate whether or not they support the plan. None indicated opposition.
II. Unit Profile: School of Mathematics

Please fill in the gray areas on this form.

<table>
<thead>
<tr>
<th>Number of Tenured and Tenure-Track Faculty:</th>
<th>Comments about Faculty/Instructors:</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 Professors</td>
<td>In addition to the tenure-stream faculty (the vast majority of which participate in undergraduate teaching), the department employs 4 contract associate or assistant professors whose duties are oriented towards teaching and administration. There are additionally 26 postdocs (whose duties include teaching), 9 faculty members associated with the Minnesota Center for Financial and Actuarial Mathematics, and 17 lecturers and teaching specialists.</td>
</tr>
<tr>
<td>9 Associate Professors</td>
<td></td>
</tr>
<tr>
<td>8 Assistant Professors</td>
<td></td>
</tr>
<tr>
<td><strong>62</strong> Total</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major(s)</th>
<th>Total # students enrolled in major as of Spring 2019</th>
<th>Total # students graduating with major as of AY 2018-2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor of Science</td>
<td>302</td>
<td>104</td>
</tr>
<tr>
<td>Bachelor of Arts</td>
<td>330</td>
<td>96</td>
</tr>
<tr>
<td>Total:</td>
<td><strong>662</strong></td>
<td><strong>200</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WEC Process</th>
<th>Date</th>
<th># Participated</th>
<th># Invited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting #1 (surveys, sections 1, 2)</td>
<td>10/19/2017</td>
<td>19</td>
<td>70</td>
</tr>
<tr>
<td>Meeting #2 (section 2, 3)</td>
<td>11/14/2017</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>Meeting #3 (curriculum, criteria)</td>
<td>2/15/2018</td>
<td>13</td>
<td>70</td>
</tr>
<tr>
<td>Meeting #4 (criteria)</td>
<td>3/20/2018</td>
<td>13</td>
<td>70</td>
</tr>
<tr>
<td>Meeting #4.5 (supplementary criteria)</td>
<td>4/3/2018</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>MathCEP Reading Group</td>
<td>10/26/2018</td>
<td>12</td>
<td>70</td>
</tr>
</tbody>
</table>
IV. Signature Page

Signatures needed regardless of Writing Plan edition. Please fill in the gray areas on this form.

WEC Faculty Liaison

Craig Westerland

Print Name

Signature

Associate Professor

Title

Date

Department Head/Chair

Peter Olver

Print Name

Signature

Professor

Title

Date

Associate Dean

Paul Strykowski

Print Name

Signature

George W. Taylor Distinguished Professor

Title

Date
V. Writing Plan Narrative, 2nd Edition

Please retain section headers and prompts in your plan.

Introductory Summary:
Briefly describe the reason(s) this unit (department, school, college) became involved in the WEC project, the key findings that resulted from the process of developing this plan, and the implementation activities that are proposed in this Writing Plan, with particular attention to the following questions: what is new in this 2nd edition of the Writing Plan? What, if any, key changes have been made to the 1st edition? What key implementation activities are proposed in this edition of the Writing Plan? (1 page maximum)

The School of Mathematics has identified communicating effectively as one of the central learning outcomes for its students. Communicating about mathematics in both spoken and written words involves a balance between the logical precision required to create new mathematical facts and the recognition of the informal language that reflects how we think about and assimilate new mathematics.

Our efforts to develop students’ skills in mathematical communication are complicated by the fact that the courses in our lower-division curriculum -- Calculus I and II, Linear Algebra and Differential Equations, and Multivariable Calculus -- emphasize computational tasks and assess these skills in a way that does not place equal emphasis on the communication of those ideas. These large service courses are not primarily designed for mathematics majors, and indeed, many majors can avoid some or all of these courses based on their previous mathematics experience.

At the upper-division level, instructors expect their math major students to engage in deeper mathematics and communicate effectively about it. Undergraduate majors regularly participate in courses at the 5000 level and above depending upon their preparation and specialization. At present, the Mathematics department places a large burden on our Sequences, Series, and Foundations courses, MATH 2283 and 3283W, to train students in the techniques of mathematical proof and clear exposition of those proofs. While many students are successful in these so called “transition courses,” members of the department agree that student performance can be improved with more practice and feedback on writing and communication.

Recognizing that training in mathematical communication requires intervention throughout the curriculum, the undergraduate curriculum committee voted unanimously to apply to the Writing-enriched Curriculum program in 2017-2018. In addition to the members of the curriculum committee, a growing core of faculty committed to taking a fresh approach to improving outcomes for our undergraduate mathematics students participated in our meetings and in the development of this plan.

In our first year of implementation, we began to make the case that promoting good mathematical writing and developing tools to train it in a systematic way are worthwhile tasks that will create richer mathematical experiences for faculty and students. This was implemented through course interventions in MATH 3283W and 5345H (Introduction to Topology) which will continue in the second year of the WEC program. We had some success in tailoring homework assignments in the
latter course to specific aspects of mathematical writing. In the former course, there was a good deal of success in implementing reflective writing assignments after quizzes. In both cases, there was some hesitance on the students’ part to fully engage in these projects; while this improved over time, it is something that we ought to address going forward.

This year we will expand our scope to include an intervention in MATH 4281 (Introduction to Modern Algebra). Additionally, we will expand our training efforts for incoming graduate students (in their capacity as TAs and graders) in MATH 8001 (Preparation for College Teaching) to include a component on teaching with writing, with the assistance of the WEC staff. Further, over the course of the next two years, we will begin an examination of how these sorts of writing interventions might be implemented in our lower level and service courses.

Section 1: DISCIPLINE-SPECIFIC WRITING CHARACTERISTICS

What characterizes academic and professional communication in this discipline?

☒ There have not been substantial revisions to this section of the Writing Plan.
☐ There have been substantial revisions to this section of the Writing Plan. (Discuss these explicitly.)

Fundamentally, writing in mathematics is characterized by logical arguments and deductions. In formal settings, this is codified in the notion of a proof – a logical argument that has its own stylized form – but even in informal communication the emphasis is on careful, internally consistent, deductive reasoning.

Good mathematical writing is characterized by clarity and precision of explanation and the use of valid and sound logical arguments to establish results. Because mathematics relies on rigorous definitions of its terms, these definitions (and associated notation) must be clear and unambiguous. Arguments are often illustrated by (but not necessarily established with) well-chosen examples and counterexamples.

Stylistically, good mathematical writing is often concise, well-organized, and follows a focused and sequential development of the argument (without unnecessary detours or descriptions). Arguments should be well-motivated (often with explicit justifications) and, in longer forms, accompanied by an introductory roadmap, clearly marked transitions, and internal summaries. Ideally, mathematical writing is tailored to its audience, acknowledging the wealth of different backgrounds in the subject. A mathematically prepared reader should be able to understand and reconstruct the argument on their own, and mathematical operations and choices may need to be explained for lay readers.

At its heart, a proof is a logical argument designed to convince the reader of the truth of a claim. As such, it must clearly convey an idea, not merely move symbols about. In longer work, good writing highlights the most critical components of an argument. Finally, as with all writing in English, mathematical writing must employ correct grammar and sentence structures.
Section 2: DESIRED WRITING ABILITIES
With which writing abilities should students in this unit’s major(s) graduate?

☒ There have not been substantial revisions to this section of the Writing Plan.
☐ There have been substantial revisions to this section of the Writing Plan. (Discuss these explicitly.)

The demands of mathematical writing are substantial, being dictated by a high bar of rigor and logical precision. This is the foundation of mathematical writing, and perhaps its most important aspect. Secondary to that, exposition should be structured to illustrate the logical flow of an argument. Finally, mathematical writing addresses the needs of the intended audience. As such, a very well-prepared mathematics major should graduate with the following writing abilities, given in those three clusters:

Precision & Rigor:

1. Assess whether an argument, whether logical or mathematical, is complete and correct.
2. Explain and justify choices in method or approach when considering a problem or question. Be able to explain their choices and show their work.
3. Know and follow conventions for mathematical exposition, including standard patterns of proof and English grammar and usage.

Exposition, Explanation, & Argumentation:

1. Employ choices in language that illustrate the logical progression of the argument. In problems and shorter forms, organize writing in ways that illustrates the goal or main idea. In writing a mathematical paper or longer forms, establish a clear plan (roadmap) for writing.
2. Draw attention to the critical components of a logical argument by highlighting themes and giving a sense of the big picture.
3. Select illustrative examples and visualizations to amplify and clarify the argument being made.
4. Write concisely, recognizing and eliminating extraneous information.

Audience & Context:

1. Write mathematics (proofs, arguments, and exposition) that a reasonably prepared reader can understand and reconstruct.
2. Consider an audience's needs and motivation when communicating mathematics and make effective choices about level of detail for non-technical audiences. The audience’s expertise and needs should guide the use of technical terms and level of detail.
3. Use presentation tools, typesetting packages, and mathematical software.

**Section 3: INTEGRATION OF WRITING INTO UNIT’S UNDERGRADUATE CURRICULUM**

How is writing instruction currently positioned in this unit’s undergraduate curriculum (or curricula)? What, if any, course sequencing issues impede an intentional integration of relevant, developmentally appropriate writing instruction?

☒ There have not been substantial revisions to this section of the Writing Plan.
☐ There have been substantial revisions to this section of the Writing Plan. (Discuss these explicitly.)

Due to the large service component of the 1000 and 2000 level classes, very little mathematical writing instruction currently occurs in these courses. Instead, most instructors focus on computation and correct answers to problems. While students write answers to problem sets and homework, they rarely are asked to reflect on their processes or provide explanation beyond a correct answer. Because these service courses serve as prerequisite mathematics for many colleges and departments across the University, it is difficult to focus on expectations for majors in these environments.

In the 3000 level classes, particularly 3283W (Sequences, Series, and Foundations) and 3592H/3593H (Honors Mathematics I/II), instructors begin to incorporate instruction on writing proofs. In these classes, as well as the subsequent 4000 and 5000 level classes (where these skills are developed further), the bulk of writing instruction focuses on the category “Precision & Rigor” described above. The category “Exposition, Explanation, & Argumentation” receives sporadic instruction at this level. Far less attention is paid to the material in the category “Audience & Context,” except for item 1 in that section (which receives a lot of instruction). Specialized courses in the Actuarial Science track pay some explicit attention to practices of reporting in the industry, but still emphasize mathematical modeling and probability.

Surveys of the faculty indicate that students commonly struggle with concision, highlighting critical components of arguments, consideration of an audience’s needs, as well as justification of choices of methods. These struggles are consistent, but are notable in the areas where our curricular survey indicated less writing instruction. With the exception of the last, there is a general willingness amongst faculty responding to the survey to address these issues in the future.

We acknowledge that there is something of a bottleneck in the structure of the major (in the 3000 level classes above which focus on writing). If a student finds an alternate or nonstandard route through the major, students can bypass these courses in a way that can impact the development of their writing skills. The faculty discussed linear algebra as a potential site for attempting additional explicit instruction in writing and as another opportunity for majors to practice writing in context. While these 3000 level classes explicitly focus on writing instruction, instructors in 4000 and subsequent courses felt that the focus of the classes is on working with and writing increasingly complex mathematics rather than explaining mathematics in prose or reflecting on processes of
problem solving. Writing instruction mostly happens by positive example or in grading comments. Additionally, many faculty indicate that in passing to the 4000 and 5000 level classes, the level of abstraction (compared to the 3000 level classes) increases substantially, which provides added pressures on students to adapt their writing skills to these new settings.

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.).

☒ There have not been substantial revisions to this section of the Writing Plan.
☐ There have been substantial revisions to this section of the Writing Plan. (Discuss these explicitly.)

Several concerns have been raised about grading practices. A common theme is that imposition of a writing component of grades will be onerous on the instructor, grader, and student. This is expressed in several ways; firstly, it is not the main purpose of a mathematics department to instruct on English grammar. Secondly, it is our tendency (and many faculty believe rightly so) to grade work entirely or largely on the correctness of the mathematics, and not the quality of the writing. A third concern is that, given the large non-native English-speaking component of our instructional workforce, we are not well-positioned to have any business grading writing.

In contrast, there is also a common feeling that our students are not adequately educated on how to write mathematics properly, and some desire on the part of the faculty to incorporate this into our grading practices. This comes with the caveat of there being a uniform distaste for prescriptive grading guidelines.

Precision & Rigor:

<p>| 1. Assess whether an argument, whether logical or mathematical, is complete and correct. | Addresses the necessary details, using valid logical statements. Points are deducted for erroneous reasoning and for omitting attention to crucial aspects of the conclusion. |
| 2. Explain and justify choices in method or approach when considering a problem or question. | a. Explains the choice of method in a way that justifies the chosen approach as the best one. Choices reflect both sound reasoning and mathematical taste. |
| | b. Defines terms, definitions, and notations near the beginning and used consistently throughout the |</p>
<table>
<thead>
<tr>
<th>Exposition, Explanation, &amp; Argumentation:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Employ choices in language that illustrate the logical progression of the argument. In problems and shorter forms, organize writing in ways that illustrates the goal or main idea. In writing a mathematical paper or longer forms, establish a clear plan (roadmap) for writing.</td>
<td>Is organized in a way that makes it clear what the author is doing and makes it clear what conclusion is reached. Deductions are made for work that lacks a clear picture of what is assumed, lack key information that helps the reader through the main part of the proof and/or lacks a clear conclusion which addresses the key issues.</td>
</tr>
<tr>
<td>2. Draw attention to the critical components of a logical argument by highlighting themes and giving a sense of the big picture.</td>
<td>In detailed exposition, addresses a short list of topics/ideas/themes, which may be subdivided into smaller subsections. Deductions are made for work that doesn't summarize or synthesize key ideas.</td>
</tr>
<tr>
<td>3. Select illustrative examples and visualizations to amplify and clarify the argument being made.</td>
<td>Clarifies the meaning of the mathematics through examples and illustrations. Examples contain requisite details to explain their meaning and value in context.</td>
</tr>
<tr>
<td>4. Write concisely, recognizing and eliminating extraneous information.</td>
<td>Is concise. Contains enough detail to be complete and no more.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Audience &amp; Context:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Write mathematics (proofs, arguments, and exposition) that a reasonably prepared reader can understand and reconstruct.</td>
<td>States what the reader is expected to assume to be true and shows sufficient detail that a reader with that level of preparation can follow. Deductions are made for work that spends too much time on easy material that should be assumed. Deductions are made for gaps in the argument that assume too much.</td>
</tr>
<tr>
<td>2. Consider an audience's needs and motivation when communicating mathematics and make effective choices about level of detail for non-</td>
<td>Tailors to the audience (well-organized, includes the right amount of detail for an identified audience). The</td>
</tr>
</tbody>
</table>
technical audiences. The audience’s expertise and needs should guide the use of technical terms and level of detail.

writing provides descriptions with enough detail that arguments can be reproduced by a peer.

(The third component of Audience & Context, regarding presentation tools and software was stricken from the set of criteria. It was felt that learning to use such tools was advised in mathematics majors, but not an essential criterion of mathematical writing.)

**Section 5: SUMMARY OF IMPLEMENTATION PLANS, including REQUESTED SUPPORT and RELATION TO PREVIOUS IMPLEMENTATION ACTIVITIES**

What does the unit 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?

How do the implementation plans of the 2nd edition Writing Plan relate to implementation activities from the 1st edition Writing Plan? What has been successful? What was not successful? How do implementation plans build on what was learned from the first year of implementation?

The mathematics department proposes several aspects to the second edition of its Writing Plan. Some of these are continued developments of activities and interventions developed in the first edition, and some are new:

1. Continued development of writing projects and rubrics for Math 5345H (Introduction to Topology) and 3283W (Sequences, Series, and Foundations).
2. Adaptation of these tools to a curricular intervention in Math 4281 (Modern Algebra).
3. Longer term discussion of the use of these methods in introductory and service courses.
4. No less than four meetings between Daniel Emery (WEC Consultant) and math faculty on development of writing instructional tools, adaptation to the math curriculum, and implementation of the writing plan.
5. TA training for grading of homework in classes with a writing emphasis.
6. A panel on the uses of mathematical writing outside of academia.
7. Further development of resources for the senior project/capstone.

In detail:

**Curricular interventions:**

In Fall 2018, (WEC Liaison) Westerland taught Math 5345H; he is teaching it again this fall. This course was a site of a curricular intervention in 2018. Some changes included in-class writing activities (developed via a Teaching With Writing workshop). The main changes, however, were to the homework assignments, which emphasized a different aspect of mathematical writing (as
enumerated in section 2) each week. In Spring 2019, Mosher taught 3283W, also implementing some writing-focused changes. Here, the major changes were to include post-quiz writing reflections.

We felt that these changes were quite effective, and students largely responded well to them. Westerland felt that the focus on writing in 5345H did lead to noticeable improvements in the quality of students’ proofs. Additionally, the shared experience appeared to generate some camaraderie in the class. One notable concern on the students’ part was that this level of writing engagement should make the course more suitable to be listed as a Writing Intensive course.

In 3238W, student feedback suggested that the writing reflections were effective instructional tools, e.g.:

- “I am very happy with my progress and have found a lot of value in this course.”
- “At first I thought it was dumb, but now I am appreciative that this was part of the curriculum.”
- “In particular, I got much better at being explicit.”

Students wrote that it increased their attention to detail and precision in their writing, and lead to a deeper understanding beyond memorization. In both courses, there were certainly students who did not deeply engage in the writing focus, perhaps regarding it as beside the point. We will need to find better ways of reaching out to these students.

The TAs in this course also offered useful feedback regarding the writing explorations:

- “… the Writing Explorations is that they open up discussion between each student and I in a way that grading and commenting on a quiz cannot. Students often bring up things that might be confusing to them or reference comments made on their quiz and it helps me better understand their thought process.”
- “One downside of the WEs is that there are less quizzes. I think the quizzes help students practice mathematical writing in a way that the WEs don't. In future iterations I think it would be good to do weekly quizzes with weekly WEs, especially if there is no turned in homework.”
- “… the continued improvement in depth & insight I've observed in the writing explorations has very much convinced me of their value... my lone fear with them is that their open-ended nature seems to confuse students, especially those for whom English is not a first language.”

In Summer 2019, WEC RA Kandola (who was vital in the development of the above curricular interventions) taught Math 4281. She continued to employ post-quiz writing reflections. She also developed a section of her course’s Canvas site for students to write their summaries of what occurred in class, as well as provide an opportunity for discussion on the material. In Fall 2019 Kathryn McCormick will be implementing and extending these changes in her section of 4281.

We envision the requested RA support to partially support the developmental efforts in these courses. Our intended RA, David DeMark, was involved as a TA for 3283W last year. As such he has direct experience with how students were responding to these writing prompts and reflection exercises, and some ideas on how to improve them this year.
In the second year of this edition of the writing plan, we intend to explore adapting these writing methods to introductory and service courses. This is envisioned as primarily the focus of MathCEP co-head Weimerskirch. These courses present an interesting challenge to curricular intervention. Students are at a much earlier state of mathematical development, so the sort of writing projects involved must be substantially different from those developed in the courses listed above. Conveniently, one of MathCEP’s focuses (through the UMPTYMP program) is teaching introductory courses, and they have a well-developed set of practices, projects, and rubrics for writing instruction in these courses. However, the participants of UMPTYMP classes are talented middle and high-school students; this presents a dramatically different target audience than first year undergraduates. Some serious thought will need to go into adapting MathCEP’s materiel to this group. One obvious concern is how to “scale up” MathCEP’s techniques to the very large intro calculus sequence, particularly in a way that does not add substantially to the TAs workload.

Meetings with WEC consultants

As an ongoing part of the development of the Writing Enriched Curriculum in the mathematics department, we request several regular meetings with WEC staff, particularly Dan Emery. This was an aspect of our first Writing Plan that was successful (although occurring less frequently than originally intended); we intend to make this an ongoing part of our current Writing Plan.

One of the main challenges of WEC in the math department will be incorporating writing instruction without disrupting mathematical instruction. Many faculty already feel pressed for time to cover the material in their courses and are hesitant to sacrifice time and focus in the classroom to writing instruction. Addressing this issue will be one of the major tasks in scaling up WEC-sponsored writing instruction beyond the limited scope described above. We seek WEC’s support and advice on how to address this topic in mathematics.

Additionally, there is a sense among some members of the faculty who are interested in adding a writing focus to their classes that they have few resources or examples at hand for how to implement this in their teaching. Again, this is a topic that we feel would be well-advised by meetings with WEC consultants. In addition to planning writing projects and assignments, the development of grading rubrics should play some role, as well as the training of TAs to grade both mathematical content and writing.

In addition to these concerns, this can be a forum for those who have incorporated writing in their instruction to talk about what has worked, and what has not. This can lead to the development of a library of projects, rubrics, and general wisdom that the department can make available to any instructor interested in adding a writing focus to their teaching. Lastly, we will solicit topics of interest from the faculty for discussion. This should help build recruitment and retention in these meetings, and allow us to tailor this time to what is most useful to the department, and synchronize with other events like guest speakers.

We imagine these meetings taking the form of lunches between Emery and interested faculty members. Alternatively (or additionally), these meetings could be coordinated with the existing Mathematics Education Seminar (organized through MathCEP). As we spent very little of the funds reserved for these lunches in our first writing plan, we are only requesting these funds for the second year of this writing plan, with the intent of carrying the existing funds forward into the first year.
TA training

TA training was included in our first Writing Plan, but never implemented, due to reasons of the late start of WEC in the math department. Our intent is to make good on that promise this year; the experience of our first writing plan will deeply inform this training process, which we intend to occur late in the fall of both years of the plan.

As part of the curricular interventions with an explicit emphasis on writing, the department seeks to organize an instructional workshop for teaching assistants involved in these and other courses. The focus here is to find methods to incorporate aspects of writing to evaluation of homework. We envision this as taking part in Math 8001 (Preparation for College Teaching) that entering graduate students take.

As is generally the case, the difficulty here will be to strike a balance between grading mathematics and grading writing. Development of a solid rubric which is flexible enough to be adapted to many different settings should be a central part of this effort. We imagine this workshop to be jointly organized between members of the math department’s undergraduate curriculum committee and WEC, in the hopes of adapting some common techniques that WEC has developed to the mathematics context.

As part of this process, we will seek feedback from those involved in the TA training regarding its effectiveness, their development of grading skills tailored to mathematical writing, and seek out commentary for improvement in future training sessions.

Panel on writing in mathematics

Fundamental mathematical writing skills – the ability to consistently and logically argue a point from first principles – is an inherently valuable skill for all of our students. Training these skills in the context of academic mathematics is well-within the abilities of our faculty. However, in recognition that the majority of our students are not likely to end up in academia, it seems prudent to explore how our graduates use their writing skills after graduation.

To that end, we intend to invite a panel of outside speakers to discuss the form that mathematical writing takes in their work, and to give insight in how to develop writing skills used in this context. We imagine the panel consisting of graduates of our program, employers of math majors and PhDs, journalists and other writers in the technical world, actuaries, and others in mathematical fields for whom written communication is a central part of their work. We have already identified a number of candidate members of the panel through our survey of “outside affiliates” at the start of the WEC program.

In addition to the development of resources for mathematical writing outside of academia, one intent of this project is to inform and inspire our majors as to the career opportunities that exist with a background in mathematics.

Like TA training, this panel was a part of our first writing plan which was never implemented, due to the late start of the writing plan. We shall use the funds appropriated in the first writing plan ($1000) to support the panel early in the second year of this writing plan (ideally Fall 2020, but this may depend upon speakers’ availabilities).
Senior project resources

Math majors write a senior project (CSE) or capstone (CLA), supervised by a member of the department. These writing projects are typically 10-20 pages in length and can offer a degree of independence in a long-term project that is uncommon in much of undergraduate mathematics. With that independence comes many opportunities for students to go astray, lose focus on the project, and manage the timing of the semester-long project poorly. Faculty supervisors, occupied with other tasks, can easily forget to check in with their advisees to see if the project is keeping to the intended timeframe.

In the first edition of the Writing Plan, the WEC RA developed a basic “contract” between students and advisors that lays out a time frame for when various components of the senior project must be done to ensure on-time completion of a well-written project. She also began the development of a set of resources for students and advisors to find interesting topics, texts, and other paths into this project. In the current edition of the writing plan, we intend for our RA to further flesh out these resources.

The CLA’s online “Research Paper” builder contains a dizzying array of resources (some with dead links), so many that the wealth of them can be overwhelming for a student. Further, many of these are not relevant for writing in math and conversely, there are few resources for the student seeking to find a topic in math. Our aim is for the WEC RA to remedy this situation, in conversation with current faculty members as well as examining similar resources at other universities.

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, teaching assistants, undergraduates, others) engaged in providing, revising, and approving the content of this Writing Plan?

In the development of the School of Mathematics’ first writing plan, surveys of faculty, students, and outside affiliates regarding mathematical writing were collected which informed subsequent discussions. Faculty members and postdocs were actively invited to participate in the four WEC meetings that lead to the development of this document. Not all did, but a substantial group of about 15 members were regularly involved in this discussion. Further email discussion amongst this group lead to more nuance to this plan.

Transcripts and summaries of these meetings were provided to the complete faculty, and several members who did not attend the meetings contributed to the discussion electronically, often in response to these reports. A first draft of the first writing plan was submitted to the faculty for a period of comment, prior to submission.

In development of the second writing plan, we sought input from the faculty, instructors, and teaching assistants who were involved in the curricular interventions in 3283W, 5345H, and 4281. We also sought feedback from students (particularly in 3283W) on the effectiveness of these interventions. This commentary informed our planned modifications and extensions of these changes. We also discussed these changes with interested faculty in a lunch meeting at the end of the first year (12 April 2019) of the writing plan, and have incorporated their suggestions. Input on
the continued adaptation of the senior project contract and associated resources was solicited from members of the curriculum committee.

As with the first writing plan, a first draft of this document was submitted to the faculty for a period of comment.

Appendices

Sample Writing Explorations for 3283W

MATH 3283W
Writing exploration 4
due Tuesday 9 April 2019

Part of quality mathematical writing is conveying your work to an audience. For the last Writing Exploration, you focused on the presentation of mathematics to your audience. For this Writing Exploration, we would like you to focus on the audience’s mathematical comprehension of your work.

Option 1: Included your graded Quiz 4 with your submission. If you took Quiz 4, consider your work on #2(b). We will consider the assumptions you made about your audience when writing the informal proof, and reflect on what would change should you formalize the proof. We encourage your to devise your own questions to answer, and here are a few that may help you get started.

- Identify the audience of your solution to #2(b). Is it yourself? A classmate? A TA or Instructor?
- What background knowledge did you assume your audience had? Could someone whom hasn’t taken this class understand it?
- Consider a formalized version of your proof. How do the assumptions about your audience change when you formalize the proof? Do they need more background information? Less?
- Between writing the scratch work and the formalized proof, which was more difficult? What are the easiest and most difficult audiences to write to?

Option 2: If you did not take Quiz 4 ... [something about exploring the many different valid choices of N, and how the fixed constraint in the definition of N affects the part that depends on epsilon.]
Math 3283W
Writing Exploration 1
Due 2/12/2019
Name: ______________________________

Writing strong mathematical proofs is just as much about quality writing as it is about quality content. These Writing Explorations are open-ended opportunities to reflect on your own writing skills, and how you can improve them. You will be graded on the effort and depth of your reflection. Hand in Quiz 1 with this exploration.

This week, you will focus on the structure of your sentences. Sentences in a quality mathematical proof should start with a capital letter, contain a subject and verb, and end with a period. They should use words in place of symbols for logical connectives and quantifiers. On Quiz 1, you were asked to write the negation of a false statement in question (2), followed by a proof of the negated statement in question (3). For this week’s Writing Exploration, you should reflect on the structure of your own sentences within that proof. Note that you should be focusing on the style and structure of your proof, as opposed to the content. You may choose to answer questions such as the following, however, it is highly encouraged that you devise your own questions to answer!
Did your sentences follow a consistent structure? What was your balance of words to symbols? If you replaced all symbols with words, would your proof still read as complete sentences? How would you rewrite some of the sentences, if any?

MATH 3283W
Writing exploration 3
due Tuesday 26 March 2019
Name ______________________________

Part of quality mathematical writing is conveying your work to an audience. For this Writing Exploration, you will focus on the presentation of the equations used in Problem 1(b) of Quiz 3. Instead of asking you to turn in a hand-written reflection, we are asking you to take the time to format your proof in \LaTeX{}, with an emphasis on the presentation of equations. One resource for aligning mathematical equations can be found here: https://www.overleaf.com/learn/latex/Aligning_equations_with_amsmath

**Option 1:** If you took Quiz 3, you should hand in your original quiz, the \LaTeX{} file containing your solution to Problem 1(b), and the PDF generated by that file. It is important to note that you are not revising your *content* of Problem 1(b); you are formatting what you submitted on Quiz 3 as \LaTeX{} document whose equations have been aligned.

**Option 2:** If you did not take Quiz 3, you should do **Option 1**, using the solution to 1(b) instead.
Feedback prompt for 3283W

The following component of the last writing exploration generated students’ commentary on the writing explorations:

**Part 2:** Everyone should complete Part 2. Because this is the last Writing Exploration of the semester, we would like you to reflect on your writing as a whole. You may answer any of the following, devise your own, or provide additional feedback.

- What does quality mathematical writing mean to you?
- How does your mathematical writing now compare to your writing at the start of the semester?
- Of the Writing Explorations this semester, did any of the themes surprise you? Are there themes you expected to see covered but didn’t?
- Which of the themes this semester were hardest for you to reflect on? Which were the easiest?
- Do you think you will continue to focus on these themes in future mathematical writing?

Sample Homework Writing prompts for 5345H

The first homework assignment:

For problems 1 and 2, write three different versions of the proof:

- The first should be careful, formal, and up to the standards of mathematical proof-writing.
- The second should be colloquial, as if you were explaining the argument to a friend in this class.
- The last should be an explanation your parents can understand.

Problems 3 through 7 are not going to be graded, but I would appreciate your answers anyway.

1. Prove that there are infinitely many prime numbers.

2. Let $f(x)$ be a polynomial. Prove that there is a number $n$ with the property that the $n^{th}$ derivative of $f(x)$ is zero.
The sixth homework assignment:

Focus on writing: Writing strong mathematical proofs is just as much about quality writing as it is about quality content. Over the next few weeks, in addition to writing up solutions to your problem sets as usual, I will ask you to focus intently on improving one aspect of your proof writing skills.

This week we will focus on finding and avoiding errors in our proof-writing. You’ll be asked to criticize and improve an argument in the first problem. Please do keep this focus in mind as you work on this the other problems this week – are your proofs as clear and compelling as they could be? What can be improved?

1. Consider the following proposition and its proof:

**Proposition 1.** Let \( f : X \to Y \) be a homeomorphism. Then \( X \) is compact if and only if \( Y \) is.

**Proof.** Since \( f \) is a homeomorphism, it sets up a bijection between the open sets of \( X \) and the open sets of \( Y \). Therefore an open covering of \( X \) admits a finite subcovering if and only if the corresponding covering of \( Y \) admits a finite subcovering. The result follows. \( \Box \)

Identify some of the flaws in this argument, and rewrite it so that it is more convincing. Alternatively to rewriting the proof (or additionally) find a different, more compelling proof.

The fifth homework assignment for 2019:

Focus on writing: Writing strong mathematical proofs is just as much about quality writing as it is about quality content. Over the next few weeks, in addition to writing up solutions to your problem sets as usual, I will ask you to focus intently on improving one aspect of your proof writing skills.

It’s often the case that a correct proof can be improved with a picture of some sort. That is: the guts of proving a mathematical fact usually lies in set-theoretic or logical arguments. But these arguments can sometimes be hard to follow without a visual guide of some sort. This is particularly true in topology and geometry. In this week’s homework, we’ll ask you to illustrate two problems (2 and 3) with a picture that illuminates the idea of the proof. Your pictures can be hand-drawn or electronically created.
The fifth homework assignment for 2018:

Focus on writing: Writing strong mathematical proofs is just as much about quality writing as it is about quality content. Over the next few weeks, in addition to writing up solutions to your problem sets as usual, I will ask you to focus intently on improving one aspect of your proof writing skills.

Last week, I encouraged you to focus on sentence structure, including when to use words instead of symbols. One way to ensure this might be to replace all symbols with words, however, this can lead to proofs that are lengthy and difficult to read. Better writing does not mean more words! This week, I would like you to focus on the concision of your sentences. Below is an unnecessarily verbose proof of one of the propositions we proved in class Friday. Can you identify how to make this proof more concise without sacrificing sentence structure?

Proposition 1. If $X$ is a space, $A \subseteq X$ is a connected subspace, and $A \subseteq B \subseteq \bar{A}$, then $B$ is also connected.

Proof. Let $X$ be a space, let $A$ be a connected subspace of $X$, and let $B$ be a set contained in the closure of $A$ that also contains $A$ itself. For the sake of contradiction, we will assume that $B$ is not connected. If that is the case, then we can write $B$ as the disjoint union of two nonempty sets. Denote the separation of $B$ as the disjoint union of $C$ and $D$, where $C$ and $D$ are disjoint, nonempty, open subsets. Because $A$ is connected, there are two possibilities. The first possibility is that $A$ is a subset of $C$. It is also possible that $A$ is a subset of $D$. Without loss of generality, suppose that $A$ is a subset of $C$. If $A$ is a subset of $C$, and $D$ is nonempty, we can exhibit an element $b$ in $B$ that is also in $D$. Theorem 17.5 of “Topology” by Munkres states the following:

Theorem 2 (17.5 of Munkres). Let $A$ be a subset of the topological space $X$.

1. Then $x \in \bar{A}$ if and only if every open set $U$ containing $x$ intersects $A$.

2. Supposing the topology of $X$ is given by a basis, then $x \in \bar{A}$ if and only if every basis element $B$ containing $x$ intersects $A$.

Since the element $b$ in $B$ is also in the closure of $A$, we know that by the abovementioned theorem, every open set containing $b$ (of which $D$ is an example) intersects $A$. This contradicts the fact that the sets $C$ and $D$ are disjoint. Because of this, no such separation of $B$ as disjoint, nonempty, open subsets $C$ and $D$ could exist.

Please keep this focus in mind as you work on this week’s problems:
Senior Capstone Project in Mathematics
Getting Started

1. Resources for project ideas:

   • Books
     – “Proofs from THE BOOK” by Martin Aigner and Günter M. Ziegler
     – “Math Talks for Undergraduates” by Serge Lang
     – “The Mathematical Tourist” by Ivars Peterson
       (associated blog: http://mathtourist.blogspot.com/)

   • YouTube videos highlighting interesting math problems
     – Numberphile https://www.youtube.com/user/numberphile
     – TED-Ed https://www.youtube.com/user/TEDEd
     – Vi Hart https://www.youtube.com/user/Vihart

   • Advanced problems from course textbooks

2. Resources for mathematical writing

   • “A Primer of Mathematical Writing” by Steven Krantz: https://arxiv.org/abs/1612.04888
   • Student Writing Support @ UMN: http://writing.umn.edu/sws/index.html
   • Assignment Planner for Research Papers from UMN Library: https://www.lib.umn.edu/ac/research-paper
Student-Adviser Mathematics Capstone Project Contract

Student: ____________________________  Adviser: ____________________________

Semester: ________ Year: _________

Project Topic/Title: __________________________________________________________

This is an optional contract to be agreed upon between the student and their adviser. If applicable, this contract should be filled out before the add/drop date of the semester. Set a date for any or all of the following project milestones, to be checked by the adviser when complete. A recommended timeline can be generated at https://www.lib.umn.edu/ac

☐ Project topic/research question decided  /  /  

☐ Provide list of resources/bibliography  /  /  

☐ Submit first draft (recommended before halfway point of semester)  /  /  

At this time, the adviser will check one of the following boxes:

☐ Writing quality meets expectations

☐ Writing quality does not meet expectations, and the student will schedule an appointment with Student Writing Support: http://writing.umn.edu/sws/index.html

☐ Submit second draft/rewrite (scheduled after SWS meeting if applicable)  /  /  

☐ Submit final draft  /  /  

Additional milestones, if desired:

☐ ___________________________________________  /  /  

☐ ___________________________________________  /  /  

☐ ___________________________________________  /  /  

Student signature and date: ___________________________________________  /  /  

Adviser signature and date: ___________________________________________  /  /  
VI. WEC Research Assistant (RA) Request Form

This form is required if RA funding is requested. If no RA funding is requested please check the box below.

☐ No RA funding requested.
☒ RA funding requested.

RAs assist faculty liaisons in the WEC Writing Plan implementation process. The specific duties of the RA are determined in coordination with the unit liaison and the WEC consultant, but should generally meet the following criteria: they are manageable in the time allotted, they are sufficient to their funding, and they have concrete goals and expectations (see below).

RA funding requests are made by appointment percent time (e.g., 25% FTE, 10% FTE, etc.). Appointment times can be split between two or more RAs when applicable (e.g., two 12.5% appointments for a total of 25% FTE request). Total funds (including fringe benefits when applicable) need to be calculated in advance by the liaison, usually in coordination with administrative personnel1.

Please note that, outside of duties determined by the liaison, WEC RAs may be required to participate in specific WEC activities, such as meetings, Canvas discussion boards, and surveys.

RA Name (Use TBD for vacancies): David DeMark
RA Contact Information: email demar180@umn.edu, phone (612) 624-9099
Period of appointment (Semester/Year to Semester/Year): AY 2019-2020
RA appointment percent time: 25% FTE

Define in detail the tasks that the RA will be completing within the funding period:

The RA will be involved in several important aspects of the projects proposed above. They will assist in the development of forms of writing instruction for Math 4281 and 3283W, working in concert with Westerland, Mosher, and McCormick. Additionally, they will establish rubrics tailored to these classes and adaptations developed for other contexts. Resources will include both libraries of such projects here at the UMN (as developed by MathCEP/UMPTYMP and current instructors who have developed such projects on their own), as well as through external sources at other universities.

Rubrics developed for these class will be adapted for use in training for teaching assistants in other writing-intensive courses. The RA will be involved in that TA training, or at least in the development of material for the training, particularly in late Fall 2019. Additionally, if useful projects and rubrics are developed, this could form portion of a presentation given by the RA at a lunch meeting between the interested faculty and a WEC consultant.

---

1 An example for determining funding for appointments can be found on the WEC Liaison Google site. This is for planning and example purposes only and cannot be used to determine final budget items for the Writing Plan.
Finally, the RA will further develop the senior project contract (started in the first year of the Writing Plan), particularly with an eye to identifying resources for students to find topics and background material for the project.

Define deadlines as applicable (please note that all deadlines must be completed within the funding period):

The RA support is intended for the first year of this writing plan. In the first semester of support, the RA will focus on development of materials for 4281 and methods for TA training. In the second semester, they will continue the development of existing resources for 3283W and the senior project.

Describe how frequently the RA will check in with the liaison:

Every two weeks, more frequently if needed under the circumstances.

Describe in detail the RA’s check-in process (e.g., email, phone, in-person, etc.):

In-person check-in is ideal, and should be suitable for at least half of the regular check-ins. Otherwise email or Skype meetings suffice.
VI. WEC Writing Plan Requests

Unit Name: Mathematics

Unit Financial Contact Name/Email: Harrydeo Singh, mathdept@umn.edu

Chart string for fund transfer: 1000-11133-20088-(EID)5011311

Financial Requests (requests cannot include faculty salary support) drop-down choices will appear when cell next to "semester" is selected

Total Financial Request: $20,500.00

<table>
<thead>
<tr>
<th>Service</th>
<th>Qty</th>
<th>Service</th>
<th>Qty</th>
<th>Service</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultation</td>
<td>2</td>
<td>Consultation</td>
<td>2</td>
<td>Consultation</td>
<td>2</td>
</tr>
<tr>
<td>Workshop</td>
<td>3</td>
<td>Workshop</td>
<td>2</td>
<td>Workshop</td>
<td>3</td>
</tr>
</tbody>
</table>

Rationale for costs and their schedule of distribution

For two semesters, a 25%FTE research assistantship at level RA3 consists of a stipend of $10,000 and overhead of $9,000. If necessary, this could be lowered to RA1, which is $9,500 stipend and $8,550 overhead. The lunch expenses of $750 each semester are to cover two lunch workshops in each semester with approximately 30 participants each time (at a rate of $12.50 per lunch).

Service Requests drop-down choices will appear when a cell in the "service" column is selected

Description and rationale for services

Consultations in the first year with Dan Emery will be focused on several topics: how to incorporate a writing focus in instruction without sacrificing time devoted to mathematics, how to scale up the results of our first small-scale curricular intervention to a larger setting, development of general writing projects that can be adaptable to many mathematics classes, and development of grading rubrics. One workshop each fall is intended as part of TA training for grading writing in those courses that currently emphasize it (e.g., 5345H and 3283W). Additionally, we intend to have four workshops over the course of the first year on the four topics of consultation listed above. In the second year, we intend to continue to explore these themes, but also expect that new topics (particularly related to adapting this program to service courses) to arise. We envision these as taking the form of discussion over lunch amongst interested faculty members and members of WEC.
Thank you for providing the Office of Undergraduate Education with a 2nd Edition Writing Plan. On behalf of the Department of Mathematics, you have requested the following funding to support that plan’s implementation.

The table below outlines the requested funds in yellow.

<table>
<thead>
<tr>
<th>Mathematics</th>
<th>Fall 2019</th>
<th>$ 9,500.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2019</td>
<td>Research Assistant</td>
<td>$ 9,500.00</td>
</tr>
<tr>
<td>Spring 2020</td>
<td>Research Assistant</td>
<td>$ 9,500.00</td>
</tr>
<tr>
<td>Fall 2020</td>
<td>Workshop lunch expense</td>
<td>$ 750.00</td>
</tr>
<tr>
<td>Spring 2021</td>
<td>Workshop lunch expense</td>
<td>$ 750.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>$ 20,500.00</strong></td>
</tr>
</tbody>
</table>

The Research Assistant has been hired by the department and will support WEC initiatives. This position has previously been funded by the department and WEC funds will cover half of the Research Assistant’s salary. As you develop your 3rd Edition Writing Plan, please provide a summary of events that includes attendance. Any carry forward you have from lunch expenses should be rolled into the third plan.

All items above have been approved by the Office of Undergraduate Education, for a total of $20,500. These funds will be transferred in full during the FY20 to your department’s EFS account string: 1000-11133-20088. We wish the department every success in this ongoing effort to support students in communicating in and about mathematics.