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Using Departmental Publications to Foster Student Creativity in Mathematics

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Cover Page Footnote

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Synopsis

This paper discusses the design and implementation of mathematical departmental publications. We argue that these publications foster students' creativity and written communication skills.

Introduction

Professional mathematicians communicate their ideas by writing and publishing their work. At the undergraduate level, the idea of creating and publishing in mathematics can seem intimidating to students. In order to develop students' writing and communication skills in mathematics, the Math and Statistics Learning Centre (MSLC) at the University of Toronto Scarborough (UTSC) launched two publications: *MSLC Magazine* and *Math in Action Journal*. In this paper, we will discuss the design and implementation of these publications. We will describe our strategy for fostering a culture of creativity through mentoring students who are writing for publication, and our conscious efforts to develop students' higher order thinking skills such as analysis, evaluation, and creativity. We will explore the value of departmental publication both for teaching undergraduate students to engage creatively with mathematics and for improving academic communication.

It is our thesis that, as Firmmender states, "Engaging students in written communication of their mathematically creative ideas positions them as practicing professionals." [6]

Outline of article

This article contains four sections. In the first section, we discuss models of creativity that we use to help our students with their writing. In the second section, we outline the purpose and history of our departmental publications. In the third section, we provide suggestions for starting a departmental publication and include some case studies of writing with high school and university students. In the final section, we offer additional advice for working with student authors who are preparing their first pieces for publication.

1. Creativity and Mathematics

One goal of education is to guide students to discover their creative faculties, their ability to create new ideas and methods, and their ability to think outside of the box. To work towards this goal, we need first understand what we mean by ingenuity and creativity. We also need tangible models for the creative process so that we can describe it to our students.

Creativity in mathematics can mean connecting previously understood notions and facts or coming up with new abstract theories. Once one has done creative work in mathematics, it is important to communicate the results as precisely and clearly as possible. Thus, written communication has a vital role in facilitating the creation of mathematical knowledge.

Ervynck recognizes three stages for mathematical creativity [5]. Stage 0 is the initial technical stage, which consists of some kind of technical or practical application of mathematical rules and procedures, without the user having a deep awareness of the theoretical foundation. Stage 1 is the stage of algorithmic activity, which consists mainly of applying mathematical techniques, such as explicitly applying an algorithm repeatedly. Stage 2 refers to conceptual and constructive activity in which mathematical creativity occurs and consists of non-algorithmic decision making [15]. An example of Stage 2 mathematical creativity could be observed in the work of professional mathematicians such as Maryam Mirzakhani who brought together several mathematical disciplines, including hyperbolic geometry, complex analysis, topology, and dynamical systems. In addition to synthesizing previous knowledge,

Maryam communicated her works to the community and left us a record of her work. Our goal for mathematics undergraduate students is to work at Ervynck's Stage 0 of mathematical creativity. Our departmental publications offer undergraduates opportunities to independently learn, connect some of the facts and notions in their own way, and discuss practical applications and then communicate their work in form of presentations and written materials. We attempt to support gradual growth in students' creative processes [14].

We will explain our understanding of creativity through Bloom's Taxonomy of Learning [2], Edward Bono's Thinking Hats model [7], and Tony Buzan's Mind Maps [4]. We share all these different models with our students, so that students can choose the model which works best for them. Not all students will respond equally to all models. Each one provides a lens for examining the creative process.

Bloom's Taxonomy of Learning. This model is well known to educators. In this taxonomy, the affective, psychomotor, and cognitive domains of learning are broken down to their various stages. The psychomotor domain deals with learning physical skills, the affective domain is about the growth of feelings and emotion, and finally the cognitive domain is about mental and thinking skills. Figure 1 describes the hierarchical relationship among each domain levels progressing from lower level to the top level.

Figure 1: Cognitive, Affective, and Psychomotor Hierarchies in Bloom's Taxonomy.

The typical activities in cognitive domain consists of remembering basic facts, explaining concepts, using them in new situations, drawing connections among ideas, and justifying and finally evaluating a standpoint. This domain of learning culminates in producing an original work. In our work, in addition to the cognitive domain, we also pay attention to the affective domain by trying to help students develop positive feelings about learning mathematical topics [2].

Edward Bono's Model of Thinking. In this model of creativity and problem solving, we classify the process of thinking creatively into six stages and represent each stage with a coloured hat. We can imagine ourselves constantly changing these hats until we find an appropriate solution to a given problem. The blue hat is responsible for defining a problem clearly, managing our use of time and flow of ideas, and assisting in communication between the different hats. Figure 2 describes the dynamic relationship among various moods of thinking according to Edward Bono' Model.

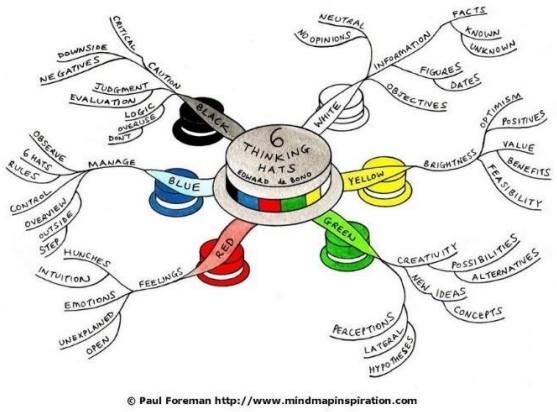

Figure 2: Six Thinking Hats [7], from https://abroun21.files.wordpress.com/2012/04/six-thinking-hats-mindmap2.jpg.

Some of the types of questions that we might ask while wearing this hat are: "What is the problem that we are facing? What are our goals and desired outcomes?" The white hat is the stage where we record whatever data our inquiry uncovers. The types of questions that we ask while wearing this hat might be: "What do I know and what don't I know about this problem?" The yellow hat represents the initial optimistic stage of thinking about a problem. It provides us with a roadmmap to our ultimate goal, and gives us the motivation to work towards it. It deals with questions like: "What are the benefits and potential positive outcomes of our proposed solutions?" The black hat represents the pessimistic stage of thinking, which is every bit as necessary as the optimistic stage, because it can help us to avoid making mistakes as we carry out our solutions. The types of questions asked at this stage might include: "What are some possible flaws of this way of thinking? What are the drawbacks of our method?" The red hat is all about emotions and intuition. The sort of questions that we might ask at this stage include:

"Is this the right approach? Intuitively, what seems to be the best way to solve this problem?" Finally, the green hat is concerned with creativity itself. While wearing this hat, we strive to bring new methods and ideas to the foreground. While wearing this hat, we might ask questions like: "Could we solve this problem more easily using another method? What other approaches might we consider?"

Mind Map Thinking. According to Tony Buzan [4], "creativity, by its very nature, implies getting away from the norm. Normal is that to which your brain has become used to; that which gives you no surprises..."

We use mind map tools to foster the process of creative thinking. To make a mind map, we begin with a concept that we want to explore. The central concept is then connected to related ideas by branches. By connecting the central idea in a mind map to more topics, we can hope to come up with novel insights. For example, Figure 2 is showing a mind map to describe a process of creative thinking.

Theory into Practice. The creativity models are not just theories for us. We share our understanding of the creativity with our students.

As a specific example of applying Bloom's creative model in students work, we will discuss the process of developing one of the materials in the *Math In Action Journal* (MIA). We will look at the article "Exploring Menelaus' Theorem in Hilbert Geometry" which was written by Yumna Habib, a UTSC student, in 2017. Zohreh was Yumna's supervisor for all stages of this work.

In her work, Yumna first provides the statement of Menelaus's Theorem in Euclidean geometry. She then defines the hyperbolic ratio of three distinct points on a given hyperbolic line. Then, she states and proves an analogue of Menelaus Theorem in Hyperbolic geometry. At the end, she mentions that Menelaus Theorem could be used as an evaluation tool for a given Hilbert Geometry to possess a hyperbolic structure. Yumna used multiple resources for her work including an article from the *Journal of Geometry* [10]. The understanding of the Euclidean version of Menelaus's Theorem in Yumna's work stands in the lowest two levels of Bloom's Taxonomy. When she tries to discuss and prove the Hyperbolic Menelaus's Theorem, she extended her previous knowledge in a new situation in order to make new connections. She continues the process of creating more links by stating the interesting fact that Menelaus's Theorem serves as a test tool for Hilbert geometries

with hyperbolic structures. This latest connection is an example of creative thinking according to Bloom's taxonomy of learning in cognitive domain.

As an example of applying Edward Bono's Thinking Hats model, Zohreh discusses the various stages of thinking with her students using colored hats to offer a tangible way of thinking about creativity. The hats help to make people more conscious of their creative process. For example, if a student is struggling to get started in solving a problem or understanding a concept then we might encourage them to "use their white hat" and gather more information about the topic of study. If a student is unable to see the flaws in their own work, then they might look at their work while "wearing the black hat".

Zohreh encourages students to create mind maps as a place to begin their writing assignments. Mind maps can help to make conscious the associative process involved in creativity. For example, the video presentation and the extended abstract are the final product of Yumna's associative process of creative thinking.

2. History and purpose of these publications

The Math and Statistics Learning Centre (MSLC) at the University of Toronto Scarborough (UTSC) was established as a collaboration between the Department of Computer and Mathematical Sciences and the Centre for Teaching and Learning both to support students taking undergraduate mathematics courses and to enrich their learning experience in mathematics in general. Various small group sessions, review modules, and seminars have been developed and offered. Special attention has been given to understanding the sources of students' challenges in learning mathematical concepts and exploring new methods to engage students. MSLC teaching team consists of a coordinator, two assistant coordinators and graduate and undergraduate teaching assistants and peers. Each year over 2,500 students' visits are recorded for tutoring by at least 1,500 hours of support in various shapes.

In order to develop students' writing and communication skills in mathematics and nurture their creative thinking, the MSLC launched its annual magazine and *Math in Action Journal* in 2014 and 2017 respectively. This paper discusses the design and implementation of these publications, which were initiated by MSLC Coordinator Zohreh Shahbazi.

Shahbazi is also an Associate Professor, Teaching Stream at the Department of Computer and Mathematical Sciences at UTSC. Parker Glynn-Adey joined MSLC as an Assistant Coordinator and has helped with preparation of the materials for the *MSLC Magazine* and *Math in Action Journal* since 2018.

We encourage the reader to look at these publications before continuing with this article. Familiarity with these publications is helpful, but not necessary.

3. *MSLC Magazine*

The *Magazine* issues may be accessed at: https://www.utsc.utoronto.ca/mslc/mslcmagazine.

MSLC Magazine is a guide to the activities of the MSLC, and a showcase for student work. A typical issue includes material written by faculty, information about the programs offered by MSLC, and contributions from students. The magazine includes some lighter material such as cartoons and horoscopes to broaden its appeal. *MSLC Magazine* has a very narrow circulation. It is essentially an internal document. However, it is highly visible in the Center and copies are distributed continuously. As far as an academic publication goes, it has almost no external profile. The readers of *MSLC Magazine* are UTSC students and faculty. The *Magazine* is readily available in the MSLC, and we see students flipping through it in the Center while studying or waiting for tutors. Whenever a new issue comes up, a hundred hard copies are made available in the MSLC and UTSC Student Centre and a copy is posted online.

We view the mission of MSLC as primarily being a venue for students to publish. Students who submit their work are MSLC undergraduate teaching assistants, and MSLC users. Some students submitted their work as the result of projects and reading courses, which are supervised by the MSLC Coordinator or Assistant Coordinators.

We also published the work of a high school student in the 2019 issue. This student worked with Parker to prepare her article. She participated in the University of Toronto Math Mentorship Program, an enrichment program for high school students who would like to learn about mathematics at a higher level and do some original research. We will discuss this work in the Case Studies section in the paper (Section 7).

As Table 1 shows, there is always a faculty submission to the magazine. These pieces give faculty a space to do recreational writing and help to engage our colleagues in the creation of the issue. In addition, the faculty articles set the required standard for students' work.

Year	2015	2016	2017	2018	2019
Students	4	4	6	4	6
Faculty	2	2	3	3	3

Table 1: Submission numbers by year.

3.1. Where did MSLC Magazine come from?

To stimulate student creativity, and provide an opportunity to practice writing, Zohreh included a research assignment in her fourth-year classical geometry course MAT D02. This course typically consists of 30-40 computer science and mathematics students. Students are instructed to select a topic from eight available areas of geometry and write a ten-page report about it in the format of a typical mathematics journal article. The areas from 2018/2019 were: Finite Geometry, Affine Geometry, Combinatorial Geometry Polytopes, Contact Geometry, Algebraic Geometry, Complex Geometry, Projective Geometry. The task is very challenging for mathematics students, because they have had few opportunities to practice writing about mathematics.

To ease students into writing, the assignment is scaffolded, and they are provided with an adequate level of support. Part of the scaffolding consists of arranging mini presentations. These are four one-hour lectures spread throughout the term. In each session, students are divided into groups of three. Each student is given ten minutes to explain their topic to the group, and the other two students listen, record their observations and evaluate the presentation. This is an opportunity for students to practice expressing their thoughts in a low-stakes environment.

However, one research assignment in one course can only go so far in improving students' writing skills in mathematics. This inspired Zohreh to design and develop new tools to provide opportunities for her students to develop their skills further. *MSLC Magazine*, launched in 2014, is one of such tools.

Figure 3: Mini-Presentations.

The magazine includes articles related to mathematics or statistics, challenging problems, and more general math-related content. We also arrange interviews with students and teaching assistants to inquire about their experiences teaching and learning mathematics.

4. Creation process and formative outcomes

Each year, Zohreh forms and leads a committee including current and former students from mathematics, statistics, journalism and art together with faculty members to prepare the issue. Each member is assigned a specific role. For example, the communication officer is in charge of organizing meetings and collecting content from authors. The first task is to decide the theme for the year's issue. For example, the theme of the 2019 issue was creativity. Then, each member reached out to students or faculty members who might be able to contribute. During regular meetings, various issues were discussed, such as possible ways to improve and promote the magazine. Generally, the committee is eager to improve the magazine further.

What makes us excited about this initiative is looking back and seeing how far the Magazine has come. The *MSLC Magazine* has had a profound impact on some of our students by raising their confidence in producing new materials. This is evident from the fact that more students show interest in courses that require them to produce articles for the magazine. For example, 22 students took their project courses with Zohreh since 2015.

Figure 4: The Cover Page of 2019 *MSLC Magazine*.

Another formative outcome is that one of the students who wrote an article for the magazine won the UTSC library research award in 2017.

For some students, the experience of working with *MSLC Magazine* has significantly shaped their careers. Manaal Hussain was a MATD02 student and is now a program advisor in the Department of Arts, Culture, and Media at UTSC. Manaal is the *MSLC Magazine* designer. She collects the final versions of articles and images and designs the format of each issue. Below, Manaal shares her thoughts about how their experience with the Magazine has shaped her education and career.

> "My involvement with the Math and Statistics Learning Centre started back when I was an undergraduate student looking to find a space where I fit in. Experiencing the space as a student inspired me to seek opportunities within the Centre wherein I could further impact students in their learning. Not only did it help me grow professionally, it also helped me to explore my creativity when it came to teaching as well. I am very aware of the negative misconceptions surrounding mathematics, and statistics as fields of study. These misconceptions I often find discourage students from pursuing these fields, and those who do have a hard time looking for support. Working on development and design of the *Magazine* for the Centre gave me the opportunity to engage such students and show the fun and creative parts of the field and talk about how math could be more than numbers and functions."

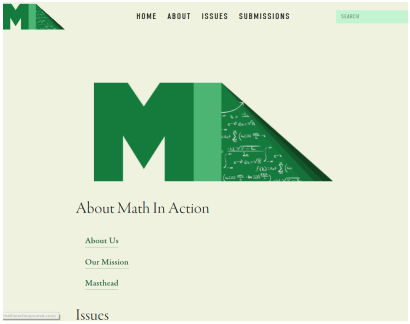

Figure 5: The Home Page of *Math in Action Journal*.

5. *Math in Action Journal*

The online journal may be accessed at: https://www.mathinactionjournal.com/.

Math in Action (*MIA*) is a video journal that provides a platform for mathematics undergraduates to share their work with peers and academics alike. Typically, it features research projects from senior undergraduate classes. Submissions to *Math in Action* are accepted in the form of video presentations with two-page extended abstracts, and students are encouraged to use creative approaches for presenting their work.

Upper-year students who have submitted to the *Math in Action Journal* can continue to expand their communication skills through providing feedback to their junior peers by reviewing and editing submissions.

Each year, Zohreh and Parker invite a couple of students who did exceptional work on their research reports in their upper level mathematics courses to submit their work to *MIA*. Then, they provide about 6-10 hours of support per student to supervise them further while they create their videos and extended abstracts.

Another mechanism to encourage submission to *MIA* is department reading or project courses. Each year several students take reading or project courses with Zohreh and Parker. They hold regular meetings with each student to discuss the topic from various resources such as journal papers. Zohreh and Parker encourage students to check the *MIA* items to broaden their familiarity with mathematics. In addition, the journal link is available on the main page of the Department of Computer and Mathematical Sciences.

5.1. Where did the Math in Action Journal come from?

To develop students' writing and communication skills further, Zohreh initiated *Math in Action Journal* in 2017. *Math in Action* is an undergraduate research journal developed using a Teaching Enhancement Grant. The journal aims to provide a platform for mathematics undergraduates to share their work with peers and academics alike. *Math in Action* has also been used for research assignments in senior undergraduate and graduate mathematics courses. We hope that this journal will help to foster student engagement in mathematics programs. It will also give researchers the opportunity to interact with students and inspire greater interest in their fields, with the hope of creating stronger generations of future researchers. Submissions to *MIA* are accepted in the form of video presentations, along with a two-page extended abstract. Students are encouraged to use creative approaches in presenting their work.

The idea of a video journal came after designing online calculus and precalculus modules using funding that Zohreh received from the Council of Ontario Universities (COU). The project team developed 12 online modules for undergraduate students looking to improve their skills in mathematics fundamentals. Each module consisted of video lessons and an animation. (The online modules may be found at: https://www.utsc.utoronto.ca/math-instruction/.) The experience in designing and launching mathematical videos and animations inspired Zohreh to develop a video journal in which students publish their research work as videos.

6. How to start a departmental publication

In this section, we will outline how to create a departmental publication in your department. Of course, every department is different. There are different resources available at every institution and everyone's time is limited. To start a departmental publication, you may adapt our advice to your situation.

The first, and most important part of starting a publication, is finding some enthusiastic students who are willing to contribute material. Parker has had some success working with students from mentorship programs and math clubs. As outlined above, student work can also be generated through projects in upper-year classes and reading courses. Olivia Rennie and Manaal Hussain, key members of the editorial team, were Zohreh's students and teaching assistants.

It is important to define the roles and responsibilities of each team member clearly in the beginning. For our publication, MSLC coordinators and assistants are reviewers of the submitted articles and make comments on accuracy and structure. The editor helps with the language improvement of written materials. The magazine designer collects the final versions of all articles and images and designs the format of each issue. The communications officer is responsible for scheduling meetings, collecting submissions, sending them to reviewers and editors for possible improvements, and making sure the tasks are done on time. The MSLC coordinator is the editor in chief of the magazine and oversees the whole process. The illustrator produces creative images, which resonates with the theme of that issue and articles.

We recommend seeking funding for your departmental publication. An approximate budget would be $3,200 per year for one issue. In addition to printing costs, there is considerable work for editing and laying out a publication. If possible, compensate your layout team. If you start an on-line journal, then the costs can be greatly reduced. We provide some approximate values for our costs:

- Printing cost $1,500
- Editorial work $500
- Communications officer $500
- Designer $500
- Illustrator $200

Contact other people in your department who might be willing to contribute material. Graduate students, post-docs, and colleagues can provide material which might help flesh-out a publication. When approaching others, be sure to make them aware of the low stakes of publishing in your departmental publication. Be sure that they are aware of the tone or style of your proposed publication.

Once you have a team ready, with some material ready to publish, begin considering layout and design. These are the final touches of starting a departmental publication. At UTSC, we worked with several graphics designers before contacting the university print shop. They had in-house designers who were able to assist us in illustrating the *MSLC Magazine*.

Outline of starting a departmental publication:

1) Apply for grants from your institution.
2) Find some enthusiastic students and colleagues who will contribute to the content.
3) Find a team of people to help edit the journal.
4) Find people with journalism or publishing experience to design the final product.

When starting a departmental publication, there is a rush to get the first issue out. Expect it to take time. Much of the initial work is about forming a team of people, and finding authors willing to write for your first issue. It might take two years to get the first issue published.

7. Case studies

Parker Glynn-Adey is an Assistant Professor at the University of Toronto. During the 2018-2019 academic year, he helped edit *MSLC Magazine* and review articles for *Math in Action Journal*. In addition to teaching at the university level, he mentors high school students in mathematics. In this section, Parker will reflect on writing an article for *MSLC Magazine* with Hillarey, a high school student, and preparing an article for *Math in Action Journal* with Henry, a third-year computer science student at UTSC. We will look at one article which eventually was published, and another which was never published.

7.1. Case study 1

Hillarey met Parker through the University of Toronto Math Mentorship Program, an enrichment program for high school students who would like to learn about mathematics at a higher level and do some original research. Together, they prepared a short article "String Figures and Tom F. Storer's Calculus" about knot theory for *MSLC Magazine*. This publication was Hillarey's first piece of creative writing about mathematics. She said that she learned a great deal about the publication process. In particular, she was surprised by how much creative effort is required to write an article for publication. The process of preparing an article for publication required many free choices and allowed for much more self-expression than writing a piece for a school assignment.

Working with high school students on a mathematical publication presents unique challenges. Among other issues: they are unfamiliar with the conventions of academic writing, they don't check their email, and they do not know how to use standard tools like LaTeX.

The situation with undergraduate students is very similar. Undergraduate students show more maturity in communication and willingness to learn new skills. At the University of Toronto, we find that many undergraduates, especially those in computer science, are familiar with LaTeX. Students who also work as teaching assistants are generally much more dependable in their responses to e-mails.

However, compared to undergraduates, strong high school students are also uniquely positioned to do good work. They have a lot of time on their hands and can engage in extensive reading and writing. A major theme of Parker's work with Hillarey has been "editing down" her writing. As her project neared completion, she made a point of writing much more than needed to convey a point and would edit it down to a manageable length with Parker's help.

To address this issue of unfamiliarity with writing conventions, Parker showed Hillarey a lot of material. Often he would send her away with three or four articles and advise her to look at them "with soft eyes." The goal was for her to notice patterns of writing that she could later emulate in her own article. Small tasks like identifying all the definitions in an article were helpful to develop a sense for the form of mathematical writing.

Communication with high school students is difficult because they do not yet have experience with conventional channels of academic communication. As academics, we are used to checking our e-mail frequently. When working with students, it is important to establish clear guidelines for communication. For example, by setting particular days of the week to check e-mail. It is also important to establish regular face-to-face meeting times with any student who you are writing with. Communicating revisions and modifications by e-mail is difficult and time consuming.

7.2. Case study 2

Henry was a third-year computer science major at UTSC when he started to work on a publication for MIA with Parker. He is familiar with LaTeXand

electronic communication. Henry and Parker met during regular office hours held at the MSLC. One struggle that Parker had while working with Henry was keeping progress consistent. Some weeks, Henry would show considerable progress in his work, and other weeks there would be almost no progress. For students, and professors, it is easy to be stuck in the "busyness trap" where flexible tasks like writing can be delayed indefinitely [3].

When Henry first approached Parker for support while writing his article, he had an unformatted document that covered the main points he wanted to address. The article was going to be about Sturm chains and roots of real polynomials. He had the bare bones definitions needed, and a statement of Sturm's theorem without any motivation or explanation. There was significant work to be done in order to bring the article up to a publishable standard.

Henry and Parker met at the MSLC during Monday afternoons office hours. They met almost every week to tweak and improve the article. It was often difficult for Henry to engage in writing outside of office hours. The result was slow, but steady, progress on the article. As the article was nearing completion, and was about to be submitted to *Math in Action Journal*, Henry went on his co-op term. This is a full-time work placement for Computer Science students, which immerses them in the world of programming and corporate life. As a result, Henry's progress ground to a halt. He became hard to contact, and impossible to meet. Eventually, the Sturm chains project slowly collapsed.

The issue that bogged down the project was that there was nothing at stake for Henry. He had approached Parker with a desire to write-up an interesting result. It was motivated by curiosity and a desire to make something of a project. However, it was not associated with any particular course and did not need to be completed. The incentive of publishing an article as an undergraduate was not strong enough to keep Henry working on the article. After several e-mail exchanges, it became clear that Henry was no longer able to commit time to the project, and we had to lay it down.

This can happen to any writing project. There must be a real and significant reason to complete a project. For this reason, we find that students who submit their final course work to *MSLC Magazine* or *MIA Journal* tend to publish. They have already invested a significant amount of time and energy chasing after a final grade, and they would like to see their work in public.

For students who are not motivated by publication, it is difficult to generate enough intrinsic motivation to complete writing projects, which might last several months, and require consistent commitment.

8. Techniques for working with students

In this section, we offer some advice to help boost students' confidence in their mathematical writing. Supervision of students' work is most effective when the students feel that they are in a flexible and supportive environment. First and foremost, we must acknowledge the student's stake in their project. As Hennessey says "People are most creative when they are motivated primarily by the interest, enjoyment, satisfaction, and challenge of the work itself—i.e., by intrinsic motivation. [9]"

8.1. Teach them standard tools

To produce mathematical articles of publishable quality, students must learn the LaTeXtypesetting language. For Hillarey's article on knot theory, there were lots of knot diagrams to create. It would have saved weeks of editorial delays if she knew how to produce these diagrams herself. When mentoring a student through the publication process, it is helpful if they learn the standard tools, such as LaTeXor Mathematica [1], [8].

8.2. Hold them beside each other

When a student is preparing an article for publication, they often have difficulty in identifying what needs to be improved to bring it up to a professional standard. They do not know the conventions of mathematical prose and cannot sense what needs to be improved. Generally, people are much stronger at comparing things than evaluating them in a vacuum. An exercise that Parker has found helpful is to compare students' work with a model. By looking at an expert specimen together with a work in progress, authors-in-training can identify places where their work can be improved to bring it to a higher standard.

8.3. You must take the initiative

When helping a student to prepare work for publication, you must always take the initiative. Students are hesitant to contact their advisors or mentors. Set aside time to review the work in progress of your students.

Students submitting work to a departmental journal will need some support and feedback on their work. There should be enough lead time for your student to respond to any comments you make before meeting in person.

8.4. Monstrous first drafts

Perfectionism holds many people back from writing. Often, we feel that a perfect vacuum is better than an imperfect first draft. As mentors to writers, who are trying to express their thoughts creatively, we can only work with the materials that are presented to us. It is important to encourage first drafts and emphasize the revision process. If a student seems hesitant in their writing, you can even set them the task of writing a "monstrous" first draft. Encourage them to produce large amounts of writing, in order to have some material to work with. Do not be harsh or judgmental about these drafts. They're a sign of definite progress from the blocked writer [11, 12].

8.5. Read it out loud

Reading a piece of writing out loud is a powerful exercise. It reveals subtle flaws in pacing and sentence structure that would otherwise go unnoticed. When preparing an article for publication, we will read it out loud with a student two or three times. This exercise provides an opportunity to discuss the work line by line, sentence by sentence [13].

9. Conclusion

The process of mathematics publication is challenging for undergraduates. By starting departmental publications, we can create resources which are valuable for both developing students' written and communication skill and improving their higher order thinking skills such as analysis, evaluation, and creativity. Furthermore, such publications can be incorporated in course designs and research assignments to engage students in mathematics research.

References

[1] Patrick Bahls and Patrick Wray. "LaTeXnics: The effect of specialized typesetting software on stem students' composition processes." *Computers and Composition*, **37**: 104–116, 2015.

[2] Benjamin S Bloom et al. Taxonomy of educational objectives. vol. 1: Cognitive domain. *New York: McKay*, **20**: 24, 1956.

[3] Robert Boice. "Procrastination, busyness and bingeing." *Behaviour research and therapy*, **27** (6): 605–611, 1989.

[4] Tony Buzan. *Make the most of your mind*. Simon and Schuster, 1984.

[5] Gontran Ervynck. "Mathematical creativity." In *Advanced mathematical thinking*, pages 42–53. Springer, 2002.

[6] Janine M Firmender, Anna Dilley, Christina Amspaugh, Kathryn Field, Steven LeMay, and Tutita M Casa. "Beyond doing mathematics: Engaging talented students in mathematically creative writing." *Gifted Child Today*, **40** (4): 205–211, 2017.

[7] Paul Foreman. "Mindmap inspiration summary of six thinking hats." http://www.mindmapinspiration.com/six-thinking-hats-mind-map-paul-foreman/, 2008. Accessed 2020-07-09.

[8] Gary Gray and Francesco Costanza. "Experiences and lessons learned teaching latex to university students." *TUGboat*, **24** (1):124–131, 2003.

[9] Beth A. Hennessey and Teresa M. Amabile. "Creativity." *Annual Review of Psychology*, **61** (1): 569–598, 2010.

[10] József Kozma and Árpád Kurusa. "Ceva's and Menelaus' theorems characterize the hyperbolic geometry among hilbert geometries." *J. Geom*, **106** (3): 465–470, 2015.

[11] Anne Lamott. "Shitty first drafts." *Wardle and Downs*, pages 527–31, 1994.

[12] Anne Lamott. *Bird by bird: Some instructions on writing and life*. Anchor, 1995.

[13] Joseph GR Martinez and Nancy Conrad Martinez. *Reading and writing to learn mathematics: A guide and a resource book*. Allyn and Bacon Boston, 2001.

[14] Jelena Pavlović and Slavica Maksić. "Implicit theories of creativity in higher education: A constructivist study." *Journal of Constructivist Psychology*, **32** (3): 254–273, 2019.

[15] Bharath Sriraman. "The characteristics of mathematical creativity." *Mathematics Educator*, **14** (1): 19–34, 2004.