

Project Description

Enhancing Students' Understanding of Calculus Through Writing

Introduction

This project seeks to investigate the usefulness of the Writing to Learn (WTL) pedagogy in the teaching of MTH 121: Introductory Calculus. While WTL has been used extensively as a teaching tool in fields such as English, psychology, and medicine for many years, this approach represents an exciting innovation in undergraduate mathematics education. Instead of passively sitting through a lecture or rote performing calculations, students engaging with the WTL pedagogy participate in a variety of writing activities (both inside and outside of the classroom), work in groups, and apply course content to explain solutions to real-world problems. In this setting, students can not only demonstrate a deeper conceptual understanding of calculus, they can also mature into more effective communicators and develop useful skills in collaboration, critical thinking, and problem solving. This classroom approach aligns itself with Elon's mission to "nurture a rich intellectual community characterized by active student engagement," and to provide a "challenging undergraduate curriculum grounded in the traditional liberal arts and sciences."

The success of the proposed research will serve as a model within the department of mathematics and statistics, within Elon University, and within other universities across the nation for measuring the effectiveness of other innovative pedagogical approaches in the classroom. It will also fill a much-needed gap in the literature on the scholarship of teaching in learning in mathematics by being the first study to measure the effects of WTL on students' conceptual understanding of calculus.

Proposal Outline

The remainder of the proposal is organized as follows. In Section 1, I give the scholarly context of the proposed work, including a discussion of prior research results concerning the effects of

WTL on affect and achievement in calculus. My goal in this section is to convince the reader that WTL is a viable pedagogical approach to improving student learning in calculus. In Section 2, I describe of the types of writing activities that will be employed during the project. The purpose here is to give specific examples of how I will implement the WTL pedagogy on a day-to-day basis. In Section 3, I lay out the objectives and outcomes of the proposed research. I describe explicitly the methods and frameworks that I will use to measure the effectiveness of the writing activities mentioned in Section 2. I conclude the proposal by discussing my dissemination goals (Section 4) and budget and timeline issues (Section 5).

1 Scholarly Context

The research literature suggests that students' difficulties in mathematics can be related to their beliefs that the subject consists only of meaningless symbols and operations [11]. These findings show that the overwhelming majority of such students possess one or both of the following traits:

- **Rote Conception of Mathematics.** Students in this category do not realize that there are concepts behind the procedures. Their procedural understanding encourages them to learn by memorization [12].
- **Negative Feelings Toward Mathematics.** These students generally suffer from some combination of: math anxiety, low self-confidence, low enjoyment of mathematics, lack of motivation, and a failure to see value in mathematics [14].

Some mathematics educators have suggested that students may be encouraged to change their conceptions of mathematics through the use of a WTL approach in the classroom [11], that WTL may benefit students' development of conceptual understanding [5], [13], and that writing is an effective and practical tool for teaching problem solving in mathematics [1]. Noted WTL proponent, Syrene Forsman, provides the following practical rationale [4]:

As teachers we can choose between (a) sentencing students to thoughtless mechanical operations and (b) facilitating their ability to think. If students' readiness for

more involved thought processes is bypassed in favor of jamming more facts and figures into their heads, they will stagnate at the lower levels of thinking. But if students are encouraged to try a variety of thought processes in classes, they can, regardless of their ages, develop considerable mental power. Writing is one of the most effective ways to develop thinking. (p. 162)

In addition to developing higher levels of thinking, writing in mathematics has been shown to help students [10]: (1) become aware of what they know and do not know and what they can and cannot do; (2) connect their prior knowledge with what they are currently studying; (3) summarize their knowledge, thereby allowing teachers to gain insights into their understanding; (4) raise questions about new ideas; and (5) construct mathematical knowledge for themselves.

Throughout this project, students will engage in several writing activities that encourage them to build their own ideas and construct their own knowledge. This active-learning approach not only reaffirms Elon's commitment to engaged learning, but it also helps students think deeply as they create the mental structures necessary to understand and explain calculus concepts.

2 Proposed Writing Activities

Combining the writing-focused recommendations of the National Council of Teachers of Mathematics [8] as well as the proven instructional strategies of the National Institute of Literacy [9], mathematics education researchers have put forth the following four recommendations for WTL in the mathematics classroom [2]. Students should write:

1. to keep ongoing records about what they are doing and learning,
2. in order to solve math problems,
3. to explain mathematical ideas, and
4. to describe learning processes.

To address these recommendations, I propose to use the following types of writing activities based on [2]: free writing, biographies, learning logs and journals, summaries, word problems, and formal writing.

FREE WRITING.

Free writing will involve writing nonstop for a fixed amount of time, usually just a few minutes. Free writes won't allow time for students to agonize over grammar or spelling; rather, they will encourage students to think freely and raise questions about important concepts in calculus.

BIOGRAPHIES.

This type of narrative non-fiction writing will encourage students to write descriptively and to identify significant events, personality traits, turning points, and impacts on a person's life. Such writing will be used to stimulate student interest in calculus concepts and its role in solving real-world problems.

LEARNING LOGS AND JOURNALS.

Students will use these weekly writing vehicles to respond to class discussions, to make connections between real-life and course content, and to reflect on themselves as learners. This on-going writing will be of fundamental importance as I measure the growth of students' conceptual understanding of calculus throughout the course.

SUMMARIES.

In this activity, students will identify main ideas, discriminating between information that is essential and information that is merely interesting. It is here that students will organize key ideas into logical patterns, especially when they are learning large amounts of concepts and calculus vocabulary terms.

WORD PROBLEMS.

Students will assume the role of writing their own calculus word problems, some of which may appear on quizzes or tests. Research of Winograd [16] suggests that students, when asked to write original word problems, will write more interesting and challenging ones than textbook problems.

FORMAL WRITING.

My primary implementation in this category will come in the form of a research project. Assigned in the last few weeks of the semester, the research project will require students to work in groups to tackle a challenging real-world problem on a topic not previously studied during the course. Students will thus have the opportunity to hypothesize and explore their problem as they work to discover and explain its solution to a non-specialist audience.

3 Project Objectives

The purpose of this research is to examine the effect of WTL on the conceptual understanding of students in introductory calculus courses. Specifically, I will seek answers to the following questions:

1. Does using the WTL pedagogy give evidence of improved student achievement in calculus?
2. Does this method give evidence of increased skills in problem solving?

3. Does writing in the classroom improve the attitude of students toward learning calculus concepts?
4. What are students' beliefs and attitudes about writing as a learning tool?

If supported, the WTL pedagogy will be tested in MTH 121 courses during the 2012–2014 academic years. To measure the effectiveness of the method in helping students understand and improve attitudes toward calculus concepts, I will employ a mixed-method approach, using both quantitative and qualitative methodologies [3]:

Pre- and Post-tests

To measure growth in conceptual understanding, students will take pre- and post-tests which address important course concepts. The post-test will be the same questions as the pre-test (or similarly formatted questions of a comparable level and complexity) and will be embedded in the course's final exam.

To measure improved problem solving skills, I will develop questions to be used on all three course exams which allow students to demonstrate their understanding, synthesis, and application of concepts. The complexity of the problems will increase over time and will build upon previously-addressed concepts. The rubrics adapted for this application will consider the level of student understanding of the problem, the application of procedures used to solve the problem, and the accuracy of their written solution.

Error Classification System

In addition to using pre- and post-tests, I also plan to develop an error classification system, based on the work of Movshovitz-Hadar, Zaslavsky, and Inbar [7], to determine if WTL helps students improve their conceptual understanding in calculus. The data for this part of the study will come from the writing activities mentioned in Section 2. The error classification system developed by Movshovitz-Hadar, Zaslavsky, and Inbar classifies student errors according to the following six categories: (a) Misused Data, (b) Misinterpreted Language, (c) Logically Invalid Inference, (d) Distorted Theorem or Definition, (e) Unverified Solution, and (f) Technical Error. I plan to use this model, and Hiebert and Lefevre's [6] framework of conceptual understanding, as a starting point to describe categories that emerge from my data for classifying students' errors in calculus; which has not been previously done.

Attitudes Toward Mathematics Inventory

To measure students' feelings and beliefs about calculus, I will use the Attitudes Toward Mathematics Inventory (ATMI) [15]. The ATMI was designed to investigate the underlying dimensions of attitudes toward mathematics, and it was constructed to address factors reported to be important in research. Specifically, the 49-items aim to assess:

1. **Confidence:** designed to measure students' confidence and self-concept of their performance in mathematics.
2. **Anxiety:** designed to measure feelings of anxiety and consequences of these feelings.

3. **Value:** designed to measure students' beliefs on the usefulness, relevance, and worth of mathematics in their life now and in the future.
4. **Enjoyment:** designed to measure the degree to which students enjoy working mathematics and mathematics classes.
5. **Motivation:** designed to measure interest in mathematics and desire to pursue studies in mathematics.

4 Dissemination Goals

The outcomes of the proposed research will allow me to publish and present my findings to the mathematics community, thereby furthering my development as a teacher-scholar. My goal for this project is to publish at least 2 papers on this research (there are several high-quality, peer-reviewed journal options) and to give at least 3 national conference presentations. These conferences are the national meeting of the American Mathematical Society (AMS) (January 2014) and the national meetings of the Mathematical Association of America (MAA) (August 2013 and August 2014).

Additionally, I will share my research results and classroom materials with my department. In recent semesters, the department of mathematics and statistics has participated in monthly discussions related the curriculum of MTH 121. Such discussions are important not only because MTH 121 is a core course for students at Elon, it is also a crucial gateway course for potential mathematics and statistics majors. My goal is to continue to play an active leadership role in these discussions by keeping the department informed at each stage of the project. Furthermore, I plan to post all writing activities created from this project to our department's Moodle site, along with appropriate grading rubrics and advice for implementations/extensions.

5 Timeline

Due to IRB rules, work involving student data cannot be analyzed while the students are enrolled in the class. Consequently, there will be a delay in the initial analysis of data.

Fall 2012 <ul style="list-style-type: none">• Develop writing prompts• Develop pre/post-tests	Spring 2013 <ul style="list-style-type: none">• Begin Fall data analysis• Coding	Summer 2013 <ul style="list-style-type: none">• Finish analysis from Fall/Spring• Present at MAA (8/13)
Fall 2013 <ul style="list-style-type: none">• Write first article• Present at AMS (1/14)	Spring 2014 <ul style="list-style-type: none">• Begin Fall data analysis• Coding	Summer 2014 <ul style="list-style-type: none">• Finish analysis from Fall/Spring• Write second article• Present at MAA (8/14)

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