PERCEPTIONS OF LEARNING IN A CALCULUS COURSE INFUSED WITH MULTIMODAL WRITING

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Student multimodal writing has gained attention in the teaching and learning of mathematics with the anticipation that these assignments will benefit student engagement and learning in a variety of ways. This study investigates students' perceptions of learning in a post-secondary calculus course, which contained four multimodal writing assignments. A course designed with multimodal writing is described along with student-generated products and feedback. Study results suggest that multimodal writing may assist students with understanding the complexities of calculus content and increase collaboration and engagement.

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Numerous researchers have recommended engaging post-secondary students in writing-to-learn activities in various forms such as reflective writing (e.g. Ryan, 2011). In recent years, multimodal writing has garnered attention with student access to readily available digital and technological tools (e.g. Bezemer, & Kress, 2008). Shepherd (2018) explains that students often have extensive extracurricular experience with digital and multimodal writing but struggle to see its connection to academic writing. Multimodal writing represents an opportunity to build on students' extracurricular understandings and interests to promote learning within a particular subject. Multimodal writing is writing that integrates text, images, visuals, and sounds (e.g. short video reflections, or blog posts). The potential benefits of multimodal writing for student learning have been explored and often focus on 21st century literacy skills (e.g. Ball, Sheppard, & Arola, 2018). Some research has been documented on effects of multimodal writing in mathematics learning at precollegiate levels (e.g. Freeman, Higgins, Horney, 2016; Pytash, Kist, & Testa, 2017), but limited research has been documented in post-secondary mathematics.

In mathematics education, a growing body of research has prioritized the challenge of engaging all learners (e.g. Schoenfeld, 2016) at the post-secondary level. Braun (2014) explored student engagement and learning through writing and identified four types of mathematics writing: personal, expository, critical, and creative. Multimodal writing can take on any of these types but differs in its considerations of varying audiences, expectations, and formats (e.g. digital video). The goal of this study is to investigate how the inclusion of multimodal writing may affect students' perceptions of learning in a post-secondary calculus course. Study components addressed the following research questions:

1) How may post-secondary students' perceptions of learning mathematics change in a calculus course infused with multimodal writing assignments?
2) What are post-secondary students' perceptions of the usefulness of multimodal writing assignments in a calculus course?

Theoretical Framing

Two constructs grounded study design to address the research questions. Cobb's complementary perspective (1994) and Anderson and Krathwohl's (2001) revised version of Bloom's Taxonomy. Analyzing students' perceptions of learning was viewed through the complementary perspective of constructivist and sociocultural theories of learning as conceptualized by Cobb (1994). Cobb accounts for both what students learn and how they interact and communicate (often through writing) to do so. A revised version of Bloom's Taxonomy also provided a lens for understanding student learning as increases in knowledge (e.g. calculus concepts) and engagements in cognitive processes (e.g. analyze). Anderson and Krathwohl's (2001) taxonomy includes four major knowledge dimensions: factual, conceptual, procedural, and metacognitive. It also contains six major categories of cognitive processes: remember; understand; apply; analyze; evaluate; and create (Anderson & Krathwohl, 2001). The processes are hierarchal in complexity with create representing the highest complexity. For the purposes of this study, their six cognitive processes with definitions were included directly into data collection instruments for student consideration. Definitions of these processes are appropriately provided in the results section of this paper.

Methods

Context and Participants

This study took place in one section of an applied calculus course at a midsize private university. The instructor had taught this course previously three times before revising to include multimodal writing assignments. The course was designed with foci of disciplinary content and student multimodal writing. The instructor aimed to engage all students while attending to the intense learning demands of a post-secondary calculus course. To help with the challenge of meeting these learning demands, students read the first seven chapters of McGuire's (2018) book, *Teach Yourself How to Learn: Strategies You Can Use to Ace Any Course at Any Level.* The book includes strategies focused on metacognition, mindset, and emotions. Over the first ten weeks of the semester, students wrote a short reading reflection on each assigned chapter. The reflection for the chapter on emotions was adapted into a multimodal writing assignment.

A particular demand in this applied calculus course was students responding to many contextual calculus problems. Such problems regularly require solution strategies that are not prescribed in the problem. For instance, one exam problem in this course is as follows.

> A restaurant chain is considering adding a vegetarian dinner to the menu. The marketing manager collects data to determine the following equations.
>
> $$Revenue: R(x) = 0.075x^2 + 41.74x \; dollars \; when \; x \; dinners \; are \; sold$$
>
> $$Cost: C(x) = 3993.37 + 13585\ln(x) \; dollars \; for \; x \; dinners$$
>
> How many dinners does the restaurant need to sell to maximize profit?

Solution strategies for this question can vary and may include writing a profit equation. Questions of this nature were typical on tests and exams in this applied calculus course and were challenging for many students. Furthermore, thinking required to solve such problems would likely be characterized in higher cognitive processes (e.g. evaluating) as found on the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001).

Twenty-one students completed this course and represented a variety of majors along with varying levels of preparedness to engage with calculus concepts. Of the twenty-one students, seventeen agreed to participate in the study at the beginning of the semester. Twelve students were in the first year and five were in their second year of college.

Four multimodal writing assignments were created by the calculus instructor in consultation with a writing professor. These assignments were completed by all students in the course and are summarized in Table 1.

Table 1: Multimodal Writing Assignments

Assignment Name	Description
1) Write Letter Home (individual)	Students explained scope and purpose of course, their approaches to learning, and how they planned for success.
2) Produce a Podcast Episode (groups of two or three)	Students wrote a script to explain two major concepts to audience of future applied calculus students. Podcast had interview format and encouraged students to have fun and incorporate humor. Podcast recordings were submitted.
3) Create Educational Materials (groups of two or three)	Students wrote full explanations of how to approach and carry out all steps in answering a multipart difficult calculus word problem about absolute maximums and minimums. Audience was future applied calculus students in need of tutoring.
4) Write an Email (individual)	Students read the chapter, "How Your Emotions Affect Your Motivation and Learning" from the book, *Teach Yourself How to Learn: Strategies You Can Use to Ace Any Course at Any Level* (McGuire, 2018). Students wrote a reading reflection in the form of an email to a classmate who forgot to read the assigned chapter. Informal writing style typical of an email was encouraged.

Students wrote for a real audience in the sense that they were aware that the instructor planned to use their multimodal writing products with future applied calculus students. Students were also encouraged to share their products with family members in the first assignment and with classmates in the other three assignments for studying purposes. For example, groups of students exchanged products for assignment three to help prepare for an exam.

Data Collection and Analysis

Data was collected in three ways: pre-course questionnaire, post-course questionnaire, and student multimodal writing submissions. Seventeen students completed the pre-course questionnaire. Ten of these students completed the post-course questionnaire. Questionnaire data was collected anonymously. The lower number of post-course questionnaire responses was due to student attrition and a group of student athletes traveling during the last week of class. Questionnaires were parallel in form and were written based on the study's two research questions. For example, consider the parallel structure of a pre-course questionnaire prompt and a post-course questionnaire prompt in Table 2.

Table 2: Sample Parallel Questionnaire Prompts

Pre-Course Question Sample	Think about what was required of you to demonstrate on tests/exams **in previous math classes**. Rank the following requirement from 1-never to 5-very often. Creating: Putting elements together to form a coherent or functional whole;

	reorganizing elements into a new pattern or structure through generating, planning, or producing.
Post-Course Question Sample	Think about what was required of you to demonstrate on tests/exams **in this class**. Rank the following requirement from 1-never to 5-very often. Creating: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.

Like the example in Table 2, the other questions on both questionnaires were parallel in structure and contained ranked responses. One exception was the following additional question prompt on the post-course questionnaire, "*How was this class different than your conception of 'typical' math classes? Explain.*" To analyze student responses to this prompt, each sentence for each student response was categorized under unfavorable conception or favorable conception. Selected sentences are provided in the results section.

Each questionnaire contained a section on students' perceptions on the six major categories of cognitive processes (Anderson & Krathwohl, 2001) and a section on writing in mathematics classes. Quantitative analysis included tallying response frequencies for each questionnaire prompt that contained ranked responses. For example, response frequency results for a particular question could take the form, 1: 5.9%, 2: 11.8%, 3: 41.2%, 4: 35.3%, and 5: 5.9%. The rankings of all ranked-response questions contained the language, "*Rank the following requirement from 1-never to 5-very often*" with the exception of one ranked-response question that contained more descriptive language for the ranking. This language is shared in the results section.

The multimodal writing products students submitted were also treated as data and analyzed. These products were analyzed for themes related to student learning of calculus concepts and their perceptions of learning. This thematic analysis followed Creswell's (2013) recommendations to manage data, add memos on the artifacts, and classify the memos under larger themes. Themes were documented for each multimodal writing assignment submission and then noted for their frequency of occurrence across student submissions for each assignment.

Results

Results from the thematic analysis of student multimodal writing submissions are documented in Table 3. Themes related to both learning calculus content and perceptions of learning. For each assignment, the two or three themes with the highest occurrence frequencies are provided.

Table 3: Learning Themes for Multimodal Assignment Submissions

Assignment Name	Learning Theme
1) Write Letter Home (individual)	• Focus on calculus as a study of change • Appreciation/surprise regarding use of technology to replace tedious math work by hand • Recognition that this course is different in activities and expectations from other math courses taken
2) Produce a Podcast Episode (groups of two	• Focus on concept of derivative and its applications • Incorporate podcast theme of how to be successful in applied

or three)	calculus
3) Create Educational Materials (groups of two or three)	• Explanation of difference between absolute and relative extrema • Mention metacognitive strategies from book, *Teach Yourself How to Learn: Strategies You Can Use to Ace Any Course at Any Level* (McGuire, 2018) • Focus on checking reasonableness of answers
4) Write an Email (individual)	• Connect reading contents to learning current course topics • Encouraged application of reading contents to test preparation (e.g. deeply understanding underlying concepts)

Themes related to both what and how students learn. Themes provide evidence that multimodal writing assignments promoted knowledge gains of calculus concepts and productive approaches to learning.

Quantitative analysis of results from the pre-course and post-course questionnaires demonstrated effects to students' perceptions of learning. Results for cognitive process questions are summarized in Table 4, which also includes the questions used in the questionnaires.

Table 4: Comparisons of Cognitive Processes Ranked-Response Questions

Question	**Percentage Frequency for Rankings**
Pre-Course 1: Think about what was required of you to demonstrate on tests/exams **in previous math classes**. Rank the following requirement from 1-never to 5-very often. Remembering: retrieving, recognizing, and recalling relevant knowledge from long-term memory.	1: 0% 2: 5.9% 3: 11.8% 4: 52.9% 5: 29.4%
Post-Course 1: Think about what was required of you to demonstrate on tests/exams **in this class**. Rank the following requirement from 1-never to 5-very often. Remembering: retrieving, recognizing, and recalling relevant knowledge from long-term memory.	1: 0% 2: 0% 3: 20% 4: 70% 5: 10%
Pre-Course 2: Think about what was required of you to demonstrate on tests/exams **in previous math classes**. Rank the following requirement from 1-never to 5-very often. Understanding: constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.	1: 0% 2: 5.9% 3: 41.2% 4: 35.3% 5: 17.6%
Post-Course 2: Think about what was required of you to demonstrate on tests/exams **in this class**. Rank the following requirement from 1-never to 5-very often. Understanding: constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.	1: 0% 2: 0% 3: 10% 4: 50% 5: 40%
Pre-Course 3: Think about what was required of you to demonstrate on tests/exams **in previous math classes**. Rank the following requirement from 1-never to 5-very often. Applying: Carrying out or using a procedure	1: 0% 2: 0% 3: 11.8%

through executing, or implementing.	4: 47.1% 5: 41.2%
Post-Course 3: Think about what was required of you to demonstrate on tests/exams **in this class**. Rank the following requirement from 1-never to 5-very often. Applying: Carrying out or using a procedure through executing, or implementing.	1: 0% 2: 0% 3: 0% 4: 30% 5: 70%
Pre-Course 4: Think about what was required of you to demonstrate on tests/exams **in previous math classes**. Rank the following requirement from 1-never to 5-very often. Analyzing: Breaking material into constituent parts; determining how the parts relate to one another and to an overall structure.	1: 5.9% 2: 11.8% 3: 41.2% 4: 35.3% 5: 5.9%
Post-Course 4: Think about what was required of you to demonstrate on tests/exams **in this class**. Rank the following requirement from 1-never to 5-very often. Analyzing: Breaking material into constituent parts; determining how the parts relate to one another and to an overall structure.	1: 0% 2: 0% 3: 10% 4: 60% 5: 30%
Pre-Course 5: Think about what was required of you to demonstrate on tests/exams **in previous math classes**. Rank the following requirement from 1-never to 5-very often. Evaluating: Making judgments based on criteria and standards through checking and critiquing.	1: 5.9% 2: 17.6% 3: 29.4% 4: 41.2% 5: 5.9%
Post-Course 5: Think about what was required of you to demonstrate on tests/exams **in this class**. Rank the following requirement from 1-never to 5-very often. Evaluating: Making judgments based on criteria and standards through checking and critiquing.	1: 0% 2: 11.1% 3: 11.1% 4: 44.4% 5: 33.3%
Pre-Course 6: Think about what was required of you to demonstrate on tests/exams **in previous math classes**. Rank the following requirement from 1-never to 5-very often. Creating: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.	1: 0% 2: 18.8% 3: 62.5% 4: 18.8% 5: 0%
Post-Course 6: Think about what was required of you to demonstrate on tests/exams **in this class**. Rank the following requirement from 1-never to 5-very often. Creating: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.	1: 0% 2: 0% 3: 30% 4: 40% 5: 30%

Regarding cognitive processes, comparisons of pre-course frequencies to post-course frequencies show a general trend of higher post-course frequencies in categories closer to “very often” or in the “very often” category. This finding also stood out for the top three cognitive processes of analyzing, evaluating, and creating. This trend gives evidence of students’ perception of greater demands for higher cognitive processes as described by Anderson & Krathwohl (2001) on assessments in this calculus course compared to previously completed mathematics courses.

Students also responded to ranked-response questions regarding writing in mathematics with quantitative findings summarized in Table 5.

Table 5: Comparison of Writing Usefulness Ranked-Response Questions

Question	Ranking Descriptions and Percentage Frequencies
Pre-Course Question: Think about the writing you have completed **in your prior experiences learning math**. Use the following scale to rank how helpful this writing was for your learning and understanding of math.	• Not helpful for my learning and understanding of math: 25% • Somewhat helpful for my learning and understanding of math: 62.5% • Helpful for my learning and understanding of math: 25% • Significantly helpful for my learning and understanding of math: 0%
Post-Course Question: Think about the writing you have completed **in this class**. Use the following scale to rank how helpful this writing was for your learning and understanding of math.	• Not helpful for my learning and understanding of math: 10% • Somewhat helpful for my learning and understanding of math: 30% • Helpful for my learning and understanding of math: 30% • Significantly helpful for my learning and understanding of math: 30%

These parallel pre-course and post-course questions captured students' perceptions of the helpfulness of writing for their learning and understanding of mathematics. Ranked-response frequencies demonstrate a strong trend in students' perceptions towards higher levels of helpfulness in writing completed in the applied calculus course in this study compared to previous mathematics courses.

Finally, students responded to a post-course question about the calculus class in this study. Responses fell into one of two general categories of conception: unfavorable or favorable. Selected excerpts under each category have been revised for grammar and are summarized in Table 6.

Table 6: Students' Perceptions of the Applied Calculus Course

Post-Course Final Question: How was this class different than your conception of 'typical' math classes? Explain.
Category 1: Unfavorable • More graphs than I expected, and I thought there would be more equations. • It wasn't very different than any other math class I've taken other than it was a weird teaching style where it wasn't a lot of doing examples but more just definitions. I didn't love it with this teaching style. • You really need to work as a group to understand the material. I could not do it by myself like I could with Geometry and Precalculus.

Category 2: Favorable

- This class challenged me but also helped me gain new study skills.
- We learned about real life situations, such as maximizing profit when talking about a company.
- In this math class we have more writing assignments that forces students to actually understand what they are talking about.
- There were less practice problems and more class discussions.
- The way that this class is different from my prior "typical" math classes is that when learning the material, it is more explanation based rather than practicing examples.

In addition to addressing what calculus content they were to learn (e.g. maximizing profit), student responses often addressed how writing and discussing influenced how they learned. This outcome aligns with Cobb's (1994) complementary view of learning. Favorable responses outweighed unfavorable responses by an approximate ratio of three to one. This ratio along with details included in response excerpts give some evidence that students perceived this applied calculus course with its multimodal writing as beneficial to their learning.

Discussion

Study results suggest that the applied calculus course, which contained four multimodal writing assignments, affected students' perceptions of learning mathematics in a number of ways. Students recognized a greater emphasis on providing explanations compared to previous learning experiences in mathematics. In general, students also responded favorably to the multimodal writing they experienced as evidenced by increases in their perceptions of the usefulness of writing for learning mathematics. Finally, perceptions of what is required for students to demonstrate on assessments trended towards higher levels of cognitive processes as described by Anderson and Krathwohl (2001) at the end of the course.

These promising results are limited as they are based on a small sample within one applied calculus class. Further, other variables such as style of instruction and readings from McGuire's (2018) book influenced students' perceptions of learning as well. However, this study provides some evidence of the potential for multimodal writing assignments to positively affect student perceptions of learning post-secondary mathematics.

Instructors of applied calculus and other post-secondary mathematics are encouraged to consider experimenting with multimodal writing assignments with their students. Doing so may help students transfer extracurricular knowledge as recommended by Shepherd (2018) and communicate about their learning of mathematics. Study results have an additional implication of prompting further research that investigates the potential benefits of multimodal writing for engaging students in learning post-secondary mathematics.

References

Anderson, L., & Krathwohl, D. (2001). *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives.* New York: Longman.

Ball, C., Sheppard, J., & Arola, K. (2018). *Writer/designer: A guide to making multimodal projects* (2nd ed.). Boston, MA: Bedford/St. Martin's Press.

Bezemer, J., & Kress, G. (2008). Writing in multimodal texts: A social semiotic account of designs for learning. *Written Communication, 25*(2), 166-195. Retrieved from https://doi.org/10.1177/0741088307313177

Braun, B. (2014). Personal, Expository, Critical, and Creative: Using Writing in Mathematics Courses. *PRIMUS, 24*, 447-464.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13-20.

Creswell, J. (2013). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches.* (3rd ed.) Thousand Oaks, CA: SAGE Publications, Inc.
Freeman, B., Higgins, K., & Horney, M. (2016). How students communicate mathematical ideas: An examination of multimodal writing using digital technologies. *Contemporary Educational Technology, 7*(4), 281-313. Retrieved from https://dergipark.org.tr/en/pub/cet/issue/29516/316668
McGuire, S. (2018). *Teach Yourself How to Learn: Strategies You Can Use to Ace Any Course at Any Level.* Stylus Publishing, LLC.
Ryan, M. (2011). Improving reflective writing in higher education: a social semiotic perspective. *Teaching in Higher Education, 16*(1), 99-111. DOI: 10.1080/13562517.2010.507311
Pytash, K., Kist, W., & Testa, E. (2017). Remixing my life: The multimodal literacy memoir assignment and STEM. *Journal of Adolescent & Adult Literacy, 61*(2), 163-172. https://doi.org/10.1002/jaal.633
Schoenfeld, A., (2016). What makes for powerful classrooms - and what can we do, now that we know?. *MAA Focus, 36*(2), 11-14.
Shepherd, R. (2018). Digital writing, multimodality, and learning transfer: Crafting connections between composition and online composing. *Computers and Composition 48*, 103-114.