Mathematics Composition with Technology Integration for Undergraduates: Literature Review

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Throughout K-12 most students become accustomed to completing mathematics work using pen and paper. However, in both undergraduate studies and the professional sector, an understanding of mathematical typeset and digital tools is necessary for success. Further, it is crucial that students can do more than list calculations; they must clearly communicate their ideas, methods, and understandings. The prevalence of eLearning and digital submissions has increased this need as distance education instructors struggle to decipher, grade, and most of all comprehend students' thought processes via chaotic, disorganized, and handwritten submissions (Loch, Lowe, & Mestel, 2015; Quinlan & Tennenhouse, 2016; Van Dyke, Malloy, & Stallings, 2015). The inclusion of instruction in mathematical composition can combat this issue as students are forced to slow down and organize their thoughts, which can be beneficial for student communication, understanding, and effective teaching (Kuzle, 2013; Powell & Hebert, 2016; Freitag, 1997).

Today's landscape requires both the ability to communicate mathematical ideas and the use of industry standard tools to share this understanding. The following review examines the literature relating to mathematical composition, the use of digital typesetting programs in undergraduate studies, common misconceptions and barriers, as well as student perceptions of writing and typesetting in mathematics.

Title Searches, Articles, Research Documents, and Journals Researched

Using the Education Resources Information Center (ERIC), we conducted title searches using the keywords: mathematics, writing, LaTeX, typing, and composition. Restricting our search to peer-review articles, we compiled a variety of publications. The journal *Problems, Resources, and Issues in Mathematics Undergraduate Studies* proved a rich resource with articles directly related to our need. However, while our search was robust in mathematics composition, very few articles made the connection to mathematical typesetting. Of these, many were small studies from individual programs or overviews on how institutions are integrating applications like LaTeX into their curriculum. This indicates a gap in research where additional studies should be conducted. While we have included some articles focused on primary or secondary education, the majority of our review is based on undergraduate environments. The research collected represents both writing in mathematics and the use of digital tools in mathematics composition as well as student perceptions of mathematics composition and the use of digital tools.

Historical Overview

The use of digital tools in mathematics has been growing. Secondary educators have begun utilizing applications like GeoGebra to help students visualize and create stunning digital graphs (Hohenwarter & Preiner, 2007) and many upper-level mathematics courses require students typeset their submissions (Loch et al., 2015). However, when it comes to mathematics composition, we have seen a long and slow progression.

The idea of writing in mathematics is not new. Professional mathematicians are required to communicate their ideas in journals, projects, and textbooks regularly. In the late 1960s educators in England began what they called “language across the curriculum” to support discussion as a method of learning (Parker, 1985). This idea spread and America adopted the “writing across the curriculum” movement. In 1977, Janet Emig wrote a powerful piece connecting the learning theories of Vygotsky, Piaget, and Bruner to describe the effect of written communication while making a strong argument for the value of writing in education that is still continuously referenced today. Realizing the importance, many organizations began including written communication into their standards such as the National Council of Teachers of Mathematics (NCTM), who have continued to redefine the role of writing in the mathematics curriculum over the years (Freitag, 1997; Guce, 2017; Powell & Herbert, 2016). Despite the general consensus that writing in mathematics is beneficial, many educators do not integrate writing into their classroom (Freitag, 1997; Kuzle, 2013; Van Dyke et al., 2015). The writing across the curriculum movement has continued to grow and branch out into “writing to learn mathematics” which is widely documented. However, Teuscher, Kulinna, and Crooker (2015) found that less than half of teachers in their study (45%) were even familiar with the instructional method. As such, many undergraduate students are ill-prepared to communicate their ideas in writing and taking on the additional task of learning a typesetting program on their own is overwhelming. It is time that we begin adhering to the research, using the effective methods, and preparing students with the competencies they need in the workplace.

Current Findings

Communication

The literature is in consensus that writing in mathematics increases students’ ability to communicate their ideas (Kuzle, 2013; Quinlan & Tennenhouse, 2016; Loch et al., 2015, Sullivan & Melvin, 2016). Moreso, the communication of ideas is a tenant of many university outcomes and necessary for the workplace. In creating a specific course of study dedicated to the use of this instructional strategy we will ensure that these outcomes are met, and our students are prepared to impart their mathematical understanding with their peers and supervisors.

Understanding

Many studies proport that writing in mathematics increases student understanding (Kuzle, 2013; Quinlan & Tennenhouse, 2016). Powell and Hebert (2016) found a strong correlation between computational understanding and mathematics writing in elementary students. Tong (2009) makes the blanket statement, “writing enhances the understanding of mathematical concepts and aids in retaining information” (p.12) but provides no empirical evidence. Tong

(2009) does summarize previous literature in which small studies (Romberger, 2000; Taylor & McDonald, 2007) showed increases in performance. Van Dyke et al., (2015) reviews various reports showing improved assessments with writing to learn, however, their own study showed no significant difference but did note that the students using write to learn showed higher gains than the control group. Finally, Teuscher et al., (2015) examine the literature and cite 28 studies across all age groups that found small gains in academic achievement (p.58) using write to learn strategies. Perhaps more attention is needed to research any correlation between writing and understanding in mathematics. In addition, our measurement of “understanding” may not be typical as some studies designate increases in aptitudes like problem-solving or metacognitive skills, while others strictly measure standardized assessment scores.

Effective Teaching

Effective teaching is another area in which the literature reveals a consensus. The use of writing in mathematics forces students to stop mimicking examples and instead slow down, organize their thoughts, and communicate their process and understanding (Emig, 1977; Freitag, 1997; Guce, 2017; Kuzle, 2013; Van Dyke et al, 2015). In addition, the literature shows that educators agree that writing in mathematics provides teachers the ability to better spot misunderstandings or gaps in knowledge and adjust their strategies to deepen understanding (Guce, 2017; Kuzle, 2013; Powell & Hebert, 2016; Teuscher et al., 2015; Van Dyke et al., 2015).

Digital Tools

The current landscape of education and the prevalence of eLearning allow educators a unique opportunity to combine the instructional strategies of writing to learn, with the need for instruction in communication and mathematical composition through the use of digital tools. Using programs like Microsoft Word to provide background knowledge (Loch et al., 2015) and LaTeX, the industry standard (Sullivan & Melvin, 2016), allow students to gain real-world experience in the applications they will encounter in the workplace. A course dedicated to these studies will then allow students to apply this knowledge in upper-level courses with better outcomes in communication and understanding (Loch et al, 2015; Quinlan & Tennenhouse, 2016; Sullivan & Melvin, 2016; Tong, 2009).

Perceptions

Perhaps the main problem in mathematics composition is student misconceptions. Seo (2009) found that students' writing changed depending on the audience and that submissions to an English teacher contained more written explanations than submissions to a mathematics instructor (as cited in Powell and Hebert 2016). Guce (2017) identified key errors in undergraduate composition and found incorrect grammar and the misuse of symbols to be the most prevalent mistakes contributing to the idea that many students do not understand mathematics is written in complete sentences. However, the literature shows somewhat of a mixed review on student perceptions of writing in mathematics. One issue is that most studies were small and conducted at a single university or by an instructor and are not easily generalized. Van Dyke et al., (2015) cite studies which report >80% of students found writing to be helpful. However, in their own limited study, most students "did not view writing as an essential activity" (p.229) and the overall perceptions were negative. Tong (2009) conducted a review of the literature and claims "the majority of students thought writing in their mathematics course was helpful" (p. 10). Overall, the research concerning student perception is based on small samples and appears to be dependent on how writing is integrated as well as the student demographics.

On the contrary, the few resources available regarding the use of digital tools shows more favorable results in connection with student perceptions. Quinlan and Tennenhouse (2016) state that 79% of students in their study thought typesetting homework was beneficial and Loch et al. (2015) states the majority of participants would frequently use mathematical typesetting in the future. Again, this is too small a sample size to make any generalizations, but it does support the idea that in typesetting mathematics students create tangible artifacts that they are proud of which boosts intrinsic motivation for the use of digital tools. In addition, this allows for easier grading and better feedback as students integrate mathematical composition as they refine communicating their ideas while gaining real-world experience in the use of industry-standard applications.

Conclusion

The development of an undergraduate course in mathematics composition with the use of digital tools has little prevalence in the literature. What can be surmised is that writing to learn in mathematics is an effective teaching strategy that can increase problem solving skills, communication, and possibly understanding (Kuzle, 2013; Powell & Hebert, 2016; Quinlan & Tennenhouse, 2016; Teuscher et al., 2015; Tong, 2009). In addition, undergraduate students must be able to effectively write mathematics without the common errors as described by Guce (2017). While the perceptions of writing in mathematics may be varied, by using digital tools, students can create tangible artifacts and gain experience using industry standard applications that will benefit them in both upper-level mathematics courses and the workplace (Loch et al., 2015; Quinlan & Tennenhouse, 2016; Sullivan & Melvin, 2016). A large barrier that is common in the literature is time (Freitag, 1997; Kuzle, 2013; Sullivan & Melvin, 2016; Teuscher et al., 2015; Van Dyke et al., 2015). The time needed to read through student compositions and provide feedback, the time students must impart to organizing their thoughts and learning new applications, and the limited time available in the already full undergraduate curriculum which all points to the creation of a course focused on mathematical composition using technology to address this problem.

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