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Writing to Learn Mathematics: An Update

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This study investigated 309 secondary mathematics teachers', from 50 school districts, perceptions of Writing to Learn Mathematics (WTLM) strategies. A modified version of a previously validated instrument was used for an online survey (Silver, 1999). Only 45% of teachers who participated in the survey were familiar with WTLM. The majority of these teachers reported significant or some effect on student achievement in mathematics when using WTLM; however, half of these same teachers reported that WTLM required too much class time. The majority of teachers also reported at least some positive effect on student attitude in mathematics when using WTLM. Chi-squared results suggest that teachers' use of WTLM varied by teaching level. Also, teachers with higher use of WTLM had higher perceptions of effectiveness and more positive attitudes. Results indicated that the time teachers have with students and the many job requirements became obstacles for implementing WTLM.

Different phrases are used in the literature to refer to students using writing as a tool to learn concepts. The term "writing to learn" is often used (e.g., Bangert-Drowns, Hurley, & Wilkenson, 2004; Nahrgang & Petersen, 1986; Silver, 1999; Waywood, 1994) as is "writing across the curriculum" (Russell, 1990). "Content area literacy" also sometimes applies to using writing as a tool to learn content (Fisher & Ivey, 2005; Lesley, 2004). Writing to learn is associated with using writing as a tool to assist learning exclusive of using writing in content

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area classes to improve writing skills.

Writing to Learn (WTL) is grounded in the constructivist belief that learning is an active process whereby students construct their own meaning about the content being studied rather than merely being passive recipients of information imparted by teachers. Proponents of WTL assert that students who engage in writing are actively involved in the learning process (Borasi & Rose, 1989; Fisher & Ivey, 2005). Emig (1977) eloquently defends her belief that writing is unique from the three other forms of language processing—reading, listening, and speaking—as an aid to learning. She builds a case for four successful learning strategies (reinforcement, self-feedback, building connections, and active interaction with material) uniquely aligning with the four corresponding attributes of writing. Researchers (Borasi & Rose, 1989; Emig, 1977) characterized the act of writing as automatically engaging students in the learning process, making writing seem almost like a magic formula to improve learning.

Background

Writing to Learn Mathematics (WTLM) is defined as expository writing that describes or explains mathematical concepts (Pugalee, 2004), expressive writing that is "thinking on paper," exploratory writing, or personal writing (Borasi & Rose, 1989). These types of writing can occur in journals, on paper (Borasi & Rose, 1989; Clarke, Waywood, & Stephens, 1993; Jurdak & Abu Zein, 1998; Nahrgang & Petersen, 1986; Waywood, 1994), on-line (Meel, 1999), in learning logs (McIntosh & Draper, 2001), as formal papers, or in an online discussion board (Groth, 2008). It can be expository writing in the form of a letter explaining the day's lesson to a fictitious student (Evans, 1984), expressive writing in a journal describing the student's reactions to the day's lesson (Borasi & Rose, 1989), or an analysis of errors made on homework or tests (Evans, 1984). The writing can require a few in-class minutes to respond to a teacher's prompt (Jurdak & Abu Zein, 1998; Miller, 1992) or may be a longer assignment carried out as homework (Clarke et al. 1993; Meel, 1999).

Related Research

In this section we summarize research related to WTL and WTLM. We first summarize a meta-analysis on WTL across different content areas, including mathematics, and with different grade levels. We then summarize research on WTLM that produced a variety of results within different mathematics classrooms.

Numerous quasi-experimental studies have been conducted to determine the effectiveness of WTL. Bangert-Drowns, Hurley, and Wilkenson (2004) conducted a meta-analysis of selected WTL studies across content areas that involved control groups where only traditional teaching techniques were used. The meta-analysis included 48 studies, of which 28 were conducted in mathematics classrooms with elementary to college level students. The meta-analysis showed a small, statistically significant, positive improvement in academic achievement for the WTL groups. The authors dismissed the direct relationship between writing and active learning espoused by Emig (1977) and others and postulated that the improvements in learning were partly due to the development of metacognitive processes. While these results shed light on the small, but significant improvement in academic achievement, we are particularly interested in how WTLM is beneficial for students learning mathematics. Therefore, we discuss four studies that were not included in the meta-analysis, but the results of WTLM vary across the four studies.

Borasi and Rose (1989) listed the potential benefits of journal writing based upon an analysis of student journals as a "therapeutic effect, increased learning of mathematical content, improvements in learning and problem-solving skills, and re-evaluation of one's view of mathematics" (p. 363). The authors also advocate that the positive effects of WTLM are not limited to student-centered improvements, but also include better student-teacher relationships and increased teacher understanding of how to improve course instruction (Meel, 1999; Waywood, 1994) and instruction in general (Miller, 1992).

Jurdak and Abu Zein (1998) found mixed benefits for middle school mathematics students who used journal writing. The authors found a positive impact on conceptual understanding, procedural knowledge, and mathematics communications for the journal-writing group compared to the control, non-journal writing group. However, they reported no impact on problem solving, achievement, or attitudes towards mathematics.

Porter and Masingila (2000) compared the conceptual understanding, procedural skills, and routine errors of students in two college calculus classes. The two authors taught both classes, but one class of students was required to complete tasks using expository and expressive writing assignments, while the other class completed similar tasks but gave their responses verbally instead of in a written format. No significant differences were found between the two groups in the three areas (conceptual understanding, procedural skills, and errors) measured. Porter and Masingila hypothesized that the benefits of WTLM may come, not from writing, but from the act of thinking about and communicating mathematics ideas. Goss (1998) conducted a comparable study with similar results; no significant difference in academic achievement resulted between the two groups. However, Goss concluded that, while there were no differences in test scores between the two groups, students in the writing group improved the coherence of their explanations, increased ease in talking about mathematics, and more actively participated in classroom discussions.

Pugalee (2004), also compared writing to verbalization. Students described their problem solving processes verbally and in writing for a set of algebra problems. The two outputs (verbal and written) were analyzed including whether the correct solution was reached. Pugalee found that students who wrote their answers compared to those who verbalized their answer had more correct answers and were more accurate procedurally, yet there was no significant difference between the algebraic and computational errors or problem solving strategy chosen. Both outputs were analyzed for metacognitive cues with the conclusion that writing can support

metacognitive behaviors, as Bangert-Drowns et al. (1989) had hypothesized.

Three of these studies (Jurdak & Abu Zein, 1998; Porter & Masingila, 2000; Pugalee, 2004) that addressed verbal and written methods drew similar conclusions. Although writing may help with the learning of mathematics, it may not be solely the act of writing that helps. The metacognitive activity that students experience when they are required to explain their thinking (e.g. verbally, written) to others is also advantageous. Yet, Borasi and Rose (1989) found positive benefits for both students and teachers who use WTLM and Bangert-Drowns et al. (2004) found significant differences in academic achievement for students who use WTL. Therefore, it is unclear what learning methods, in particular settings, bring about substantial benefits. Some studies suggest some of the same benefits can be obtained with verbal exercises that engage active learning.

Teachers Knowledge and Use of WTLM

Although studies have shown that teachers believe using WTLM is beneficial for students, many are not using WTLM because of different obstacles. Quinn and Wilson (1997) found that the 63 mathematics teachers who were surveyed believed in the benefits of WTLM, yet most were not using WTLM routinely in their classrooms. Lack of confidence in positive results and lack of knowledge about how to implement WTLM were determined to be deterrents in Silver's (1999) survey of 117 mathematics teachers. Other obstacles such as fear that writing would consume too much class time or take too much time to grade kept teachers from using WTLM (Quinn & Wilson, 1997; Silver, 1999). Students were also seen as an obstacle. Whether it was their poor writing ability (Quinn & Wilson, 1997) or their reluctance to write in their mathematics classrooms because they "interpret their role as essentially acquiring (i.e., memorizing) facts and algorithms that can be immediately applied to the solution of given exercises; few students expect mathematics to be meaningful and fewer still

see mathematics as a creative undertaking" (Borasi & Rose, 1989, p. 347).

As can be seen by the research studies reported, there have been inconsistent reports regarding the benefits from WTLM for students and teachers; however, most WTLM studies were conducted over two decades ago and many things have changed in schools and in home life for students. With the new Common Core State Standards for Mathematics (CCSSM) (2010), the National Council of Teachers of Mathematics (NCTM) (2009; 2014) and Departments of Education encouraging communication as part of the mathematics classroom (e.g., Arizona Department of Education, 2008), it is worthwhile to explore how secondary mathematics teachers find writing assignments best used—if at all—in mathematics classes, and what obstacles these teachers see as they use WTLM.

This research is important because writing provides an opportunity to develop valuable skills in the process of solidifying secondary school mathematics content. Learning more about WTLM is also useful since this method can benefit all students (regardless of ability levels or intention to enter a math-centric career). This study is also valuable because graduates with confidence in their problem solving abilities will likely persist and succeed in their field of choice. This type of power does not emanate from rote learning in mathematics class, but from higher-level understandings of mathematical concepts.

This updated study of secondary mathematics teachers' views of WTLM may help mathematics teacher educators provide professional development for teachers to promote writing in their mathematics classroom. In addition, WTLM has also not been addressed (to our knowledge) in the literature in about 10 years (e.g., Philemon Ntenza, 2004) or much longer (e.g., Stempien & Borasi, 1985), yet it is a major focus and push of current mathematics standards. For example, one of the mathematical practices in the CCSSM is "construct viable arguments and critique the reasoning of others" (CCSSM Practice 3, 2010), defined in part as students justifying their conclusions and communicating their thinking to others. Thus,

the current study provides a research-based update on WTLM and may inform researchers' and teachers' practices.

The purpose of this study was to examine secondary mathematics teachers' perceptions about and practices using writing to learn mathematics. Specific questions driving this study adapted from Silver (1999) include:

- How are teachers using WTLM?
- How does this differ by participant characteristics?
- What are teachers' perceptions of students' achievement after using WTLM?
- What are teachers' perceptions of students' attitudes towards mathematics after using WTLM?
- What are the reported factors that promote or inhibit the use of WTLM?

Methods

E-mail addresses for Arizona school district mathematics/curriculum specialists or superintendents (in small districts) were collected from the Arizona Department of Education website. An email describing the study and a link to an online survey was sent to 153 school districts (elementary, unified, or high school) in Arizona. Six school districts responded that they were not interested in participating and one small school district's mathematics teacher declined to participate. Therefore, 146 school districts in Arizona agreed to participate, meaning district personnel received and sent the email with the online survey link to their secondary mathematics teachers. A second email was sent after three weeks to encourage teachers within participating districts to respond to the online survey. Fifty districts had at least one teacher respond to the survey during the data collection phase providing a 35% response rate for districts to the online survey.

Participants

The participants in this study were secondary (6-12) mathematics teachers who taught in one of 50 school districts

that responded to the online survey. A total of 309 secondary mathematics teachers completed the survey. Participants were grouped by district size (small, medium and large) depending on number of students enrolled in the district. A small size district had 1000 or fewer students, a medium size district had 1,001 – 10,000 students and a large size district had more than 10,000 students. Table 1 displays the distribution of teachers who responded based on their district size. Approximately twice as many female teachers (n = 159) completed the survey than male teachers (n = 78).

Respondents had varied years of teaching experience and were categorized into three groups by district size: novice (0-5 years of teaching experience), intermediate (6-15 years of teaching experience) and experienced (16 or more years of teaching experience). Table 2 displays the number of teachers across the different size districts and by their teaching experience. Forty-four percent of teachers were novice, 33% were intermediate and 23% were experienced teachers.

Table 1
Number of teacher respondents based on district size (n=309)

	Number of respondents	Percentage of total respondents
Small districts (11)	19	6%
Medium districts (27)	84	27%
Large districts (12)	206	67%

Table 2
Number of teachers by district size and experience (n=309)

	Novice	Intermediate	Experienced	Total
Small districts (11)	5	7	7	19
Medium districts (27)	28	33	23	84
Large districts (12)	103	63	40	206
Total	136	103	70	309

District Context

The school districts with participants in this study varied in ethnic background, size (number of students), number of

English Language Learners (ELL), socio-economic status, and standardized test scores. The ethnic background of the teacher participants across districts was 80% Caucasian, 9% Hispanic, 6% Asian American, 4% Native American, and 1% African American. The racial composition for students across the 50 districts based on students who took the Arizona's Instrument to Measure Standards (AIMS) in either 8th or 10th grade was 54% Caucasian, 52% Hispanic, 15% African American, 9% Asian American, and 7% Native American (Great Schools, n.d.). Although the percentage of Caucasian and Hispanic students across the districts was close, 29 of the 50 districts had a majority of Caucasian students, while 14 of the 50 districts had a majority of Hispanic students.

The average eighth grade AIMs mathematics score for students in the participating districts was 530, which was below the average of 552 for all eighth grade students in the state of Arizona. All of the districts have Title One schools within their districts as well. The participating districts tenth grade AIMs mathematics test average was 690 which was also below the average of 698 for all tenth grade students in the state of Arizona. Of the 37 districts that had tenth grade students 29 had at least one Title One school within the district.

Instrument

For this study, Silver's (1999) survey of teachers' use of WTLM was modified to: (a) align with participants involved (6-12th grade teachers), (b) reduce the amount of time teachers needed to answer the survey, and (c) update questions to include technology advancement over the past 20 years. For example, questions pertaining to college level teaching were eliminated. The demographic section of the survey was narrowed to reduce participant burden. Technology questions were modernized by adding references to the Internet. Respondents' choices were broadened from two to three response options in order to increase variability of responses while not adding to participant burden. Two open-ended questions were converted to multiple-choice questions to simplify online administration of the instrument. Finally, one

question was modified into two questions to clarify whether teachers thought WTLM improved student attitude, student achievement, or both.

The modified survey included 38 questions and a comment section; however, participants' answer choices may not have required them to answer all questions. Four questions addressed demographics, 10 questions addressed current teaching practices and attitudes towards traditional/discovery learning (e.g., Is "rote learning" essential in some areas of mathematics?), and 24 questions addressed WTLM (e.g., what types of WTLM assignments have you tried at least once?). The purpose of the survey was to identify ways that teachers used WTLM in their classrooms, what factors inhibit or promote using WTLM, and what observed influence WTLM has on student learning and attitudes. Participants who responded "not familiar" with WTLM to the first WTLM question were automatically sent to the final comment section of the online survey to avoid participants reporting on WTLM without any experience. If participants responded that they were familiar with WTLM (three possible responses), they continued the survey.

Data Analysis

Data were analyzed in three ways. First, descriptive statistics were computed for all survey variables and responses were compared across the three district sizes. Second, Chi-squared analyses were performed for categorical data to determine if differences were present in teachers' use of WTLM by grade level taught, school district size, and teaching experience as well as by teachers' perceptions of the effect of WTLM on student achievement and attitudes. Finally, open-ended responses were coded for common themes related to teachers' use of WTLM using constant comparison analysis across participants' comments (LeCompte & Preissle, 1993). To increase reliability, the researches conducted a search for negative cases. Additionally, when differences arose the researchers reached a compromise.

Results

Descriptive results and Chi-squared analyses results addressed the first four research questions. Open-ended results or themes are reported from the survey findings to address the fifth research question.

How Teachers are Using WTLM

Approximately 45% (*n* =139) of all teachers surveyed across the three district sizes were familiar[1] with writing to learn mathematics (WTLM). Figure 1 displays the number of teachers who were familiar with WTLM and their different levels of use by district size. The majority of teachers who were familiar with WTLM had used it in their classrooms (68%). Approximately 30% of teachers in each district size currently used WTLM in their classroom.

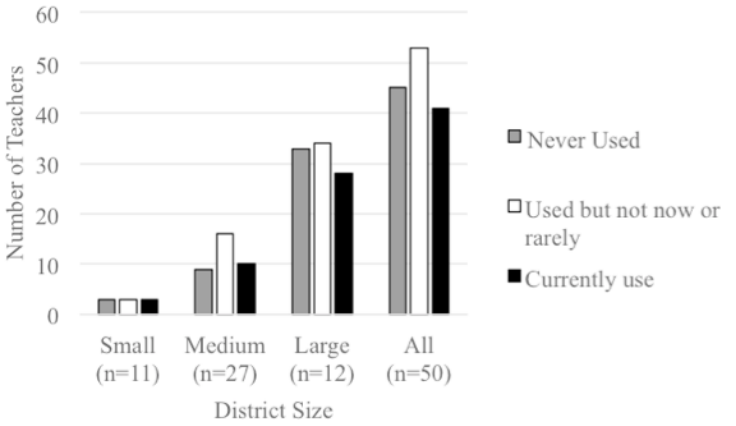

Figure 1. Number of teachers familiar with WTLM and levels of use by district size

[1] There were three categories of familiar: 1) never used WTLM, 2) have used WTLM in the past but choose not to use it or to use it rarely, and 3) have used WTLM and continue to use it with some regularity

Student Achievement and Attitudes

To determine teachers' perceptions of the effect of WTLM on student achievement and attitudes, two specific survey questions were asked: "Do you think your use of WTLM has a positive effect on students' achievement in mathematics?" and "Do you think your use of WTLM has a positive effect on your students' attitudes towards mathematics?" Teachers were given five possible responses to choose from: (a) *significant*, (b) *some*, (c) *little*, (d) *no effect*, and (d) *none*. Figures 2 and 3 display teachers' responses across the three district sizes for student achievement and attitudes in relation to the amount of class time needed to implement WTLM.

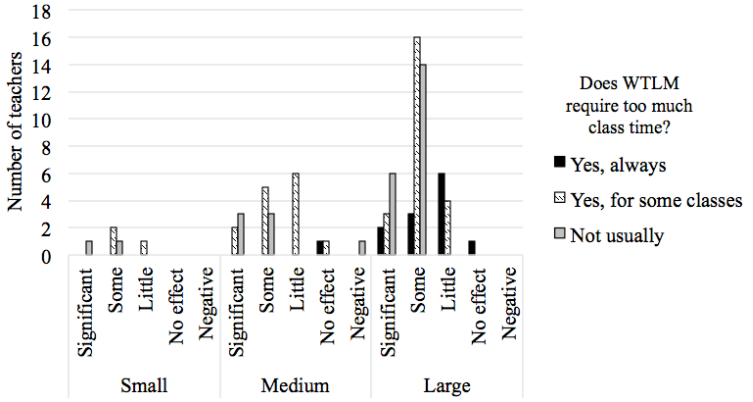

Figure 2. Teachers' perceived effect of WTLM on *student achievement* compared with classroom time.

Although 75% of teachers across the three district sizes reported significant or some effect on student achievement in mathematics when using WTLM, just over half of these same teachers (53%) reported that WTLM required too much class time (See Figure 2). On the other hand, just under half of the teachers (48%) reported significant or some positive effect on student attitudes in mathematics when using WTLM; however, the majority of these same teachers (61%) reported WTLM required too much class time (See Figure 3). There was a difference noted with teachers in large districts, with 31% of

teachers in large districts reporting using WTLM had a negative effect on student attitudes, yet 82% of these same teachers reported that WTLM did not usually require too much class time.

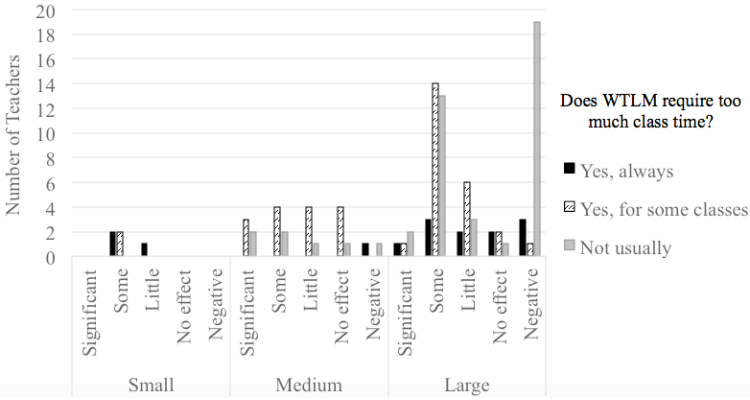

Figure 3. Teacher's perceived effect of WTLM on *student attitude* compared with classroom time.

Differences in Use by Participant Characteristics

Chi-squared results suggested that teachers' use of WTLM varied by grade level (middle, high school, or both) χ^2 (10, n = 83) = 26.64, $p < 0.01$ with more use by the high school teachers. Teachers' use of WTLM also differed by their perceptions of the effectiveness of WTLM on student achievement χ^2 (20, n = 86) = 38.86, $p < 0.01$ and student attitude χ^2 (20, n = 85) = 59.32, $p < 0.01$, with more use of WTLM reflecting higher perceptions of effectiveness and more influence on student positive attitudes toward mathematics. There were no significant differences for teachers' use of WTLM by teaching experience, or the size of the school district.

Factors that Promote or Inhibit WTLM Usage

Teachers were asked two questions about why teachers either use or do not use WTLM in their classrooms. Teachers

were given options of different factors to select based on previous research as well as an "other" option to provide factors that were not listed. Teachers could also select multiple options for each of these questions. Although these questions suggest that we asked for teachers' perceptions of why teachers use or do not use WTLM, two-thirds of the teachers were familiar with WTLM and had used it in their classrooms. Therefore, these teachers may have answered the survey related to themselves. Again, only responses from those teachers who were familiar with WTLM (n =139) were used to compare across the three district sizes. A third of our teachers who were familiar with WTLM had never used it, but we did not find differences between these teachers and the others. So we present the data without aggregating by teachers' use of WTLM across the three district sizes.

Positive factors. Teachers across the three district sizes reported that teachers make extensive use of WTLM because the department promotes it (50%) and teachers were pleased with the learning results (44%). Teachers provided 13 additional reasons in the "other" category that were coded and collapsed into two groups: outside forces and student comprehension. Outside forces were defined as reasons outside of the classroom that push teachers to use WTLM. Examples of outside forces noted by teachers included "the school promotes it", "monetary compensation", "required by the administration" and "Advanced Placement exams require WTLM." The second major factor that supported use of WTLM was student comprehension, such as, promoted thinking and learning (e.g., student communication, comprehension, used differential learning techniques, and as a formative assessment tool).

Negative factors. The two most salient reasons reported as to why teachers do not use WTLM were pressure to complete a curriculum (69%) and lack of knowledge in using WTLM (55%). An additional negative factor reported by teachers in large districts (47%) was student resistance to using WTLM. Teachers reported 12 additional reasons in the "other" category that were coded and collapsed into three groups: (a) students, (b) time, and (c) teacher beliefs. The student category was defined as students' ability to write. Some examples teachers

reported were “many students struggle with writing and can lead to frustration” and “students are writing well below academic level”. The time category was defined as teacher time constraints. Some examples teachers reported were “it will take more time to grade than traditional math work”, “no time in or out of classroom”, and “math teachers don’t have time to teach students to write”. The teacher belief category was defined as beliefs about teaching and learning mathematics. Some examples teachers reported were “writing can’t answer why someone does or does not do something”, “current assessments are multiple choice which do not require students to provide justification for their answer”.

Because participants noted time as a potential reason for not using WTLM in the mathematics classroom, we compared these results with two other survey questions related to the time element. The first question was, “In general, do you think the effective use of WTLM requires too much class time?" The second question was, “Do you think that some ‘content’ in your curriculum must be sacrificed in order to use WTLM effectively?” Respondents were given the same four choices for both questions: (a) *yes, always*; (b) *yes, for some classes*; (c) *not usually*; and (d) *no, never*. The majority of teachers (61%) who were familiar with WTLM responded that WTLM took too much class time either *always* or *for some classes*. In addition 56% of these same teachers responded that content in the curriculum was sacrificed in order to use WTLM effectively. These results were similar across the three district sizes.

Themes. Seventy teachers responded with comments about the survey and the topic of WTLM. Two general themes emerged about teachers’ use of WTLM: (a) obstacles in using WTLM and (b) a conflict between teacher beliefs and WTLM. Common obstacles discussed by teachers included lack of time, lack of training, insufficient information on the effectiveness of WTLM, as well as insufficient student writing abilities. Teachers also reported on the conflict between using WTLM and their desired way of teaching as reasons to use or not use WTLM in their teaching practices. For example, one teacher commented:

> Many of my students are learning math as well as struggling in an English class as English is their second language. I prefer the traditional way to teach them math but am open and welcome to including writing in the curriculum.

Discussion

The results reported in this paper from secondary mathematics teachers in Arizona provide similar findings to the results from two previous surveys conducted in two other states over a decade ago (Quinn & Wilson, 1997; Silver, 1999). Both Quinn and Wilson (1997) and Silver (1999) included elementary teachers in their study. Silver included college mathematics teachers as well. Silver found that most teachers had not heard of WTLM or used it rarely. Our results were similar (more than a decade later) with more than half of the secondary mathematics teachers reporting that they were not familiar with WTLM. However, we found 45% of teachers were familiar with WTLM. Although the majority of teachers are still unfamiliar with WTLM, our data suggests that more teachers are aware of and attempting to use WTLM in their classrooms than in prior studies. The fact that the majority of teachers were not familiar with WTLM is a concern, especially with the new emphasis on communication and assessments being developed that require students to answer open-ended questions (CCSSM, 2010; NCTM, 2014).

In earlier studies, researchers found that few teachers were using WTLM in their classrooms (Quinn & Wilson, 1997) and teachers lacked confidence in whether using WTLM would yield positive results for students (Silver, 1999). In the current study we found that the majority of secondary mathematics teachers who were familiar with WTLM reported positive effects on student achievement. This represents a shift from prior research, in that teachers who use WTLM are aware of the benefits for their students. There were also differences in teachers' use of WTLM by their perceptions of the effectiveness of WTLM related to student achievement and

attitude. The more teachers used WTLM, the higher their perceptions of the effectiveness of it and the larger role they indicated for WTLM to help students develop positive attitudes about mathematics.

The current study contributes to the literature regarding factors that promote the use of WTLM. These results are important for professional developers as well as administrators. The use of WTLM should be promoted across the mathematics department. If all mathematics teachers in a school are using WTLM, then teachers can offer support to each other. As discussed above, the more that teachers use WTLM in their classroom the more they see the effects on student achievement. Therefore, WTLM should be implemented over an extended period of time to see the benefits, not just tried a couple of times.

This can be done in different ways. Forty-one percent of teachers who used WTLM responded that writing prompts—defined as spontaneous in-class written responses to mathematics problems—are the most effective WTLM task. Teachers should implement small writing tasks during one entire unit and compare how their students understand the concepts for that unit with another class that did not complete the writing tasks. These writing assignments could be as small as having students write a few sentences about the mathematics they learned during the class period and the concepts they still do not understand.

As indicated in past research (Quinn & Wilson, 1997; Silver, 1999) and confirmed in this study, teachers reported multiple obstacles that inhibit their use of WTLM. Time constraints are a major obstacle in using WTLM in their classroom because of the many other job requirements (e.g., lesson planning, assessments, IEPs, parent conferences). It is noteworthy to understand why secondary teachers reported that WTLM adds to the time pressures that they experience. As one teacher who has taught more than eight years and uses WTLM at least once a week wrote on an open-ended question,

> There is so much to grade with math papers and homework and then to present and prepare lessons and now

> technology with calculators and such. As teachers, we constantly have to add one more thing. Now it is inclusion and all that goes with inclusion kids like IEP's, and then their special difficultly that we have to take into account. It is getting to be too much for the math teacher to handle.

With teachers dealing with more and more pressures to have students perform at a certain level, the time factor merits a closer examination. The majority of teachers in the current study who used WTLM reported that it always or sometimes took too much classroom time, yet more than half of these same teachers reported a positive effect on student achievement and attitude towards mathematics. Although a majority of the teachers report that WTLM has beneficial outcomes, they were not willing to sacrifice the time to use WTLM in their classroom. These results are similar to Banger-Drowns et al. (2004) who found teachers were under time constraints from outside forces (e.g., district supervisors, parents, state assessments) that limited their use of WTLM even though it has been shown to increase student achievement and attitudes (Goss 1998; Jurdak & Abu Zein, 1998). Although teachers reported that WTLM takes too much class time, we argue that this perception may have been based on classrooms and state assessments prior to CCSSM. Most past state mathematics assessments have been multiple choice, thus, encouraging teachers to move away from WTLM and more toward practicing procedures necessary to find correct answers. However, with the implementation of the CCSSM Standards (2010) and the national assessments (e.g., PARCC and SBAC), students have to answer conceptual questions, open-ended questions, and multiple-choice questions that have multiple answers. All of these types of questions require students to communicate mathematically. If teachers use WTLM in their classroom, then their students will have an advantage on these assessments.

Silver (1999) reported that teachers were not confident that student improvement would result from using WTLM and that teachers had insufficient knowledge to implement it. In the current study we found different results. In fact, we found that

secondary mathematics teachers who use or had used WTLM felt student learning was improved and that the strategies were compatible with all secondary mathematics topics and could be integrated into standard teaching practices. The problem was not their knowledge of how to implement WTLM, but how to overcome the time constraints that are a reality.

A new factor that inhibits the use of WTLM in the classroom and has not been reported in prior research is the alignment or lack of alignment between WTLM and teachers' beliefs about teaching and learning mathematics. Further exploration into the alignment or lack of alignment between WTLM and teachers' beliefs is needed. The perceived lack of alignment may be related to teachers' use of traditional direct instruction (i.e., a teacher demonstrates how to do a problem and then students mimic the teacher's actions on another problem) and the reasoning and justification processes that are needed when using WTLM. About 42% of teachers who currently used WTLM reported that they spend 0 to 50% of their instructional time using direct instruction. While 18% of teachers who did not use WTLM and 19% of teachers who had used or rarely used WTLM spent between 0 to 50% of their instructional time using direct instruction. This suggests that teachers who are using WTLM seem to not be using direct instruction the majority of the time.

The differences by teacher variables from the current study included that WTLM was used significantly more by high school teachers than middle school teachers. Although the reason WTLM is used more by high school teachers is unknown, it might be conjectured to be related to AP or IB programs at the high schools, which require students to answer free-response questions on their assessments (College Board, 2015). These types of questions require students to provide reasoning and justification that can be practiced when doing WTLM.

Limitations of this study include the small response rate (due to an online survey) and only including teachers from one state. We suggest that other studies be conducted with a larger sample that may include teachers from multiple states to identify possible differences in states. Another suggestion

would be to alter some of the questions to tease out the lack of alignment between teachers' beliefs and if and how they use WTLM.

Conclusion

The purpose of this study was to examine secondary mathematics teachers' perceptions about and practices when using writing to learn mathematics in their classrooms. Another goal was to provide an updated report on mathematics teachers' use of writing in the mathematics classroom since this has not been addressed for over 10 years and changes in the educational system require students to understand mathematics in different ways.

As researchers we would want teachers and administrators to question if the increases in student achievement and attitude expected from WTLM are worth the effort to overcome the perceived and real obstacles to using it? The obstacles are greater of course for a school or district than for a single interested teacher. In this study, nearly three-quarters of teachers who used WTLM reported that they saw some improvement in student achievement from using WTLM. If small gains are enough to pursue WTLM, then teachers may want to consider adding it to their teaching repertoire. Perhaps WTLM should be a tool teachers are introduced to or exposed to in teacher education courses and professional development so they have the option to use it depending upon their own style and personality, content, and student group.

Future research should identify ways teachers have overcome the "time constraints" as a way to assist those teachers who may not be using WTLM because of this obstacle. Another area of research that should be conducted is identifying ways that teachers could see the benefits in student learning and thinking when they use WTLM. Finally, researchers should shift their focus from the teachers to the students and investigate how using WTLM is influencing their thinking and learning about mathematics.

Secondary mathematics teachers in this survey generally agreed that WTLM helped to improve student achievement and

attitudes, even if just a little. However, these same teachers reported that they are currently not using or rarely use WTLM for various reasons. Thus, it may be a useful recommendation to provide more teachers with the background needed to develop student skills related to WTLM. While we are not suggesting that WTLM is a silver bullet, we believe that it can help improve students' understanding of mathematics. This is needed in states requiring students to take more mathematics classes during high school (e.g., Arizona Department of Education, 2008). It also complies with suggestions from multiple organizations and policy documents (e.g., Arizona Department of Education, 2008; CCSSM, 2010; NCTM, 2009, 2014) encouraging communication of mathematical thinking.

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