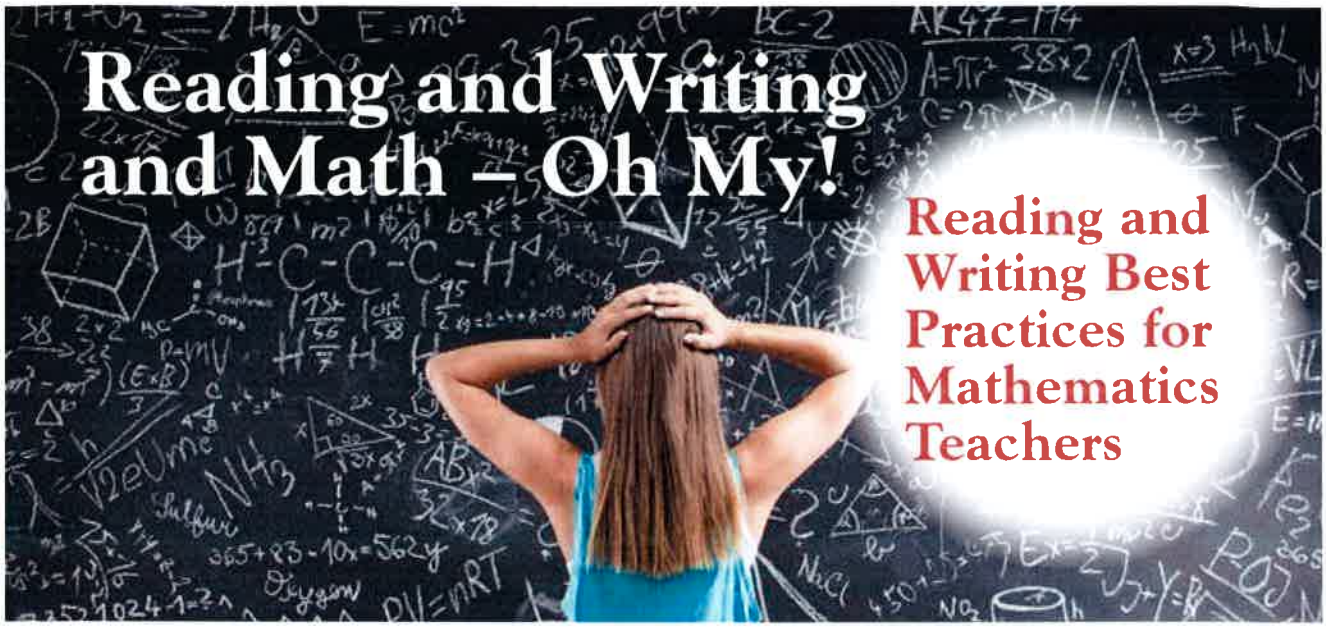

BY SALLIE AVERITT MILLER AND ERINN BENTLEY

Abstract

According to the National Council of Teachers of Mathematics (NCTM, 2010), students who have reading, writing, and listening support reap dual benefits in that they can communicate to learn mathematics and they learn to communicate mathematically. This article presents a description of a professional development workshop designed specifically for middle grades (grades 4-8) mathematics teachers to learn best practices for literacy instruction. Thus the purpose was three-fold; that is, to (1) provide professional development in reading and writing using research-based strategies to support student mathematical learning, (2) examine the perceptions of middle grades mathematics classroom teachers regarding the NCTM principle, and (3) determine the impact, or lack thereof, of the provided professional development in the teachers' classrooms.

Introduction

In recent years, there has been increased attention on reading and writing instruction within K-12 classrooms. In part, such attention has resulted from the inclusion of literacy standards in various content areas (Georgia Department of Education, 2015; National Governors Association & Council of Chief State School Officers, 2010). Researchers (Gere et al, 2013; Lattimer, 2014), as well as educational organizations including the National Council of Teachers of English (Gere et al., 2013) and the International Literacy Association (ILA, 2015) call for all teachers – across grade levels and content areas – to engage in literacy instruction. That is, teaching reading and writing cannot solely fall on the shoulders of elementary or secondary English teachers. Instead, schools must "...integrate reading, writing, speaking, and listening instruction into all subject-areas across all grade levels" (Gere et al., 2013, p. 4). Similarly, the Introduction to the ELA and Literacy Standards asserts, "instruction in reading, writing, speaking, listening, and language should be a shared responsibility" (NGA Center & CCSSO, 2010).

Faculty Context

As two faculty members specializing in reading and writing instruction within a teacher preparation program, we support this vision for comprehensive literacy instruction. As a former K-12 educator and a reading specialist, clinician, we also know that in order for content teachers to effectively integrate literacy strategies within their classrooms, they must first be knowledgeable of such strategies. Teachers may develop such pedagogical knowledge through coursework or professional development workshops. Recently, we were invited to create and facilitate such a summer workshop, specifically focused on integrating reading and writing instruction into the middle grades (grades 4-8) mathematics classroom. This 3-hour session was part of a week-long comprehensive professional development series offered to middle grades mathematics teachers across a tri-county region. The goal of the week-long series was to improve teachers' content and pedagogical knowledge for teaching middle grades mathematics. The series were developed and facilitated by members of a community outreach center (Regional Math Collaborative) housed within the Teacher Education Department of a local university and was funded by an Improving Teacher Quality State Grant Proposal (Title II). Sixteen middle grades mathematics teachers participated in the series (including the reading/writing workshop), and each was given a stipend of $500.00 and 5 Professional Learning Units (PLU).

Guiding Principles

As we developed the workshop, we first focused on the National Council of Teachers of Mathematics' Principle (2010), which states that students who have reading, writing, and listening support reap dual benefits in that they can communicate to learn mathematics and they learn to communicate mathematically. Communication, as in any subject area, is also an important skill in learning mathematics. Effective communication requires the use of four major vocabularies—reading, writing, speaking, and listening. Our workshop focused specifically on mathematics teachers' knowledge and use of instructional strategies for two of the four major vocabularies, reading and writing. With the NCTM (2000) Principle in mind, we next drew upon our knowledge and experiences using best practices for teaching reading and writing in our respective content area, language arts. We carefully chose strategies that could best be adapted for use in the math classroom. Finally, we wanted the workshop to actively engage the math teachers in using these strategies. Therefore, we invited the teachers to take on the personas of their students as they used the strategies and tools we provided to solve word problems.

Workshop Focus

The purpose for our workshop, then, was three-fold; that is, to (1) provide professional development in reading and writing using research-based strategies to support student mathematical learning, (2) examine the perceptions of middle grades mathematics classroom teachers regarding the NCTM principle, and (3) determine the impact, or lack thereof, of the provided professional development in the teachers' classrooms. To determine teachers' knowledge and perceptions of the mathematical literacy strategies, we invited teachers to complete a pre-survey and a post-survey during the workshop. To determine the impact, or lack thereof, of the professional development in the teachers' classrooms, teachers were invited to complete a third survey during the fall semester following the summer workshop experience. Descriptions of the workshop activities and survey results are as follows.

Reading and Writing Professional Development Workshops

Reading Workshop Description

The reading workshop session began with a rationale for the workshop using the following NCTM statement found in the publication *Principles and Standards for School Mathematics*. The (NCTM 2000, p. 60) states that "students who have opportunities, encouragement, and support for writing, reading, and listening in mathematics classes reap dual benefits: they communicate to learn mathematics, and they learn to communicate mathematically." Communication, as in any subject area, is also an essential part of learning in mathematics. Therefore, to be successful students must learn to communicate mathematically which requires the use of four major vocabularies (reading, writing, speaking, and listening). When the teachers attempted to identify the vocabularies there was some unexpected, lengthy hesitation.

Symbols and Unfamiliar Vocabulary

Many students may not easily comprehend mathematics texts, even when they are able to decode print materials (Cantrell, Burns, & Callaway, 2009). Mathematics texts make heavy use of symbols and unfamiliar vocabulary; use longer and more complex sentence structure; contain more words, symbols, and concepts per paragraph than other texts; and have little redundancy to help with interpretation (NCTM, 2016). Furthermore, mathematics texts are often written above the grade level of intended students (Barton & Heidema, 2002; Reehm & Long, 1996). Critical concepts that support a students' comprehension, understanding are, sometimes, buried in the text, implied, unstated, or not easily recognized. Mathematics is not an everyday language; meaning, mathematical concepts are not used outside the mathematics classroom. In reading mathematics text, readers need to analyze and expand meaning rather than condense ideas (NCTM, 2016).

Communication Builds Meaning

According to the National Council for Mathematics (2000), communication allows for the sharing of ideas and clarifying understanding; thus, students must be able to bring meaning to the printed symbols whether the symbols are letter-based or mathematical symbols. Communication builds meaning for ideas. Students must be able to translate word problems into statements that mean something to them; that is, **comprehension precedes computation**. Furthermore, listening to others' problem solving explanations allows students to develop more fully their own understandings.

Real World Word Problems

During the session, the facilitator and teachers discussed that for some students, a mathematical disability is caused by problems with language; thus, providing these students with practical, real world word problems often prove effective in motivating students by making mathematics less abstract and more interesting and relevant to them. The following are examples of real world word problems that the teachers examined during the workshop.

In the first example, the teachers worked in small groups to solve a real world shopping unit pricing problem using the K-N-W-A-M strategy. They were to

Table 1: KNWAM Word Problem Strategy (Part 1)

K	N	W	A	M
KNOW	**NOT**	**WHAT**	**APPROACH**	**MISSING**
What facts do I KNOW from the nformation in the problem?	Which information do I NOT need?	WHAT does the problem ask me to find?	What APPROACH (operation/ strategies) will I use to solve the problem?	What information is MISSING that I do not know but need to solve the problem?
Reference Table 2	*Reference Table 2*	*Reference Table 2*	*Reference Table 3*	*Reference Table 3*

Table 2: KNWAM Word Problem Strategy (Part 1I)

Item	Size	$ Price	$ Price Per Unit / Show your work!
Cream Cheese Package A Package B, Dealer's Best Brand	 6 ounces 1 pound	 $1.79 $3.89	 Best Buy:_____
Milk Carton A, Fourth of July Section Carton B, Special Buy	 1 gallon 1 quart	 $3.29 $1.25	 Best Buy:_____
Corn Oil Bottle A, New Packaging Bottle B	 64 ounces 1 quart	 $5.74 $2.29	 Best Buy:_____

Table 3: KNWAM Word Problem Strategy (Part II1)

Item	Size	$ Price
Cream Cheese Package A Cream Cheese Package B, Advertised, Brand	6 ounces 1 pound	$1.79 $3.89
Milk Carton A, Fourth of July Section Milk Carton B	 1 gallon 1 quart	 $3.29 $1.25
Corn Oil A, New Packaging Corn Oil B	64 ounces 1 quart	$5.74 $2.29

select an appropriate method for solving the problem, identify missing information, solve problem, and reflect on the reasonableness of their answers. This strategy is an adaptation of the K-W-L approach for solving word problems (Barton & Heidema, 2002). Teachers used the following three-step problem solution process.

Step 1, the teachers completed a K-N-W-A-M chart designed for solving the real world shopping unit pricing problem. K-N-W-A-M is a step-by-step process for reading comprehension (see Table 1). It is used for both reading and mathematical comprehension. The strategy engaged the teachers in the exploration of word problems as they decode the information provided, determine the question, select an appropriate solution method, and discover what other information they need but do not know. K-N-W-A-M evaluates understanding and checks for misconceptions as well as inadequate content knowledge and skills.

Step 2, the teachers were instructed to solve the practical, real world shopping unit pricing problem by identifying which items are the best buy (see Table 2).

Step 3, the teachers were asked to find the unit price for each item in the group (see Table 3). They were to determine which item offers the consumers the most product for their money.

The teachers concluded the activity by discussing the following question. *What new information have I learned while completing the K-N-W-A-M chart and solving the practical, real world shopping unit pricing problem?*

In the second example, the teachers solved a *real world time calculation problem* using the SQRQCQ strategy (see Table 4). The SQRQCQ (Survey, Question, Read, Question, Compute, Question) assisted the teachers

Table 4: SQRQCQ Word Problem

SQRQCQ	Student Response
Survey: Scan the problem to get a general idea of what it's about.	
Question: What is the problem about; what is the information in the problem?	
Read: Identify relationships and facts needed to solve the problem.	
Question: How do I solve the problem? What operations must be performed and in what order?	
Compute (or construct): Do the calculations or construct a solution.	
Question: Are the calculations correct? Does the solution make sense?	

in answering the following three questions: 1) What is the problem asking? 2) What information is critical? 3) What process should be used to solve the problem? The SQRQCQ trains a student to solve word problems in detail. The focus prompts build the problem solution; thus, providing adequate information for a successful learning outcome. The reasonableness of the solution was the culminating component to this exercise.

> Real World Word Problem: Corey is going on a backpacking trip with his family. They need to hike to their favorite camping spot and set up the camp before it gets dark. Sunset is at 8:00 P.M. It will take 3 hours to hike to the camping spot and 30 minutes to set up the camp. What is the latest time that Corey and his family can start hiking?

Using *real world math word problems* provided a logical transition for the teachers' discussion of some common, specific language difficulties that can block progress in math. These included 1) Difficulty with mathematics vocabulary, 2) Confusion by language word problems, 3) Unable to discern irrelevant information, 4) Trouble understanding written directions, 5) Struggle to explain and communicate about math, 6) Difficulty reading texts to direct student's own learning (Educational Foundation, 2002). Items 1-6 are all about communication, which requires the use of the major vocabularies: reading, writing, listening, and speaking. The teachers practiced the two previous reading problem-solving strategies that primarily addressed the above items 2-6. These strategies engaged the teachers in exploring the problem as they decoded the information provided, determined the question, and selected an appropriate solution method, discovered what other information is needed., and the reasonableness of a solution (Barton & Heidema, 2002).

The third example required the teachers to use the Frayer Model to formulate a better understanding

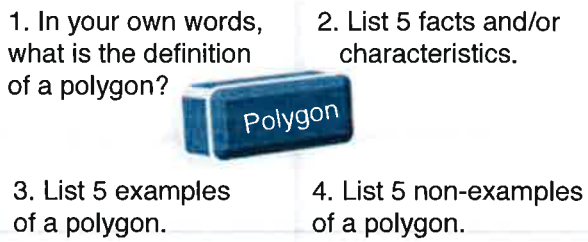

Figure 1: Frayer Model –Vocabulary

of complex concepts by asking them to identify not just what something is, but what it is not (Barton & Heidema, 2002). The following strategy specifically targets Item 1 ([d]ifficulty with mathematics vocabulary) illustrates the Frayer Model, one of many vocabulary development models for mathematics. Again, the teachers worked in small groups to complete the vocabulary concept map (see Figure 1).

Vocabulary Concept Map: Mathematical problems using polygons are relevant and very much a part of the real world; for example, angles and polygons are used by engineers, surveyors, contractors, and others. Nearly every object is some type of rectangle or triangle. Squares, triangles, and hexagons are the most common of polygons.

Writing Workshop Description

The writing workshop portion of the professional development session focused primarily on the second half of the NCTM (2000) principle: To guide

the teachers in ensuring their students "communicate [through writing] to learn mathematics" (p. 60). Both education scholars (Urquhart, 2009) and organizations (NCTM, 2000) have recognized that students benefit from writing in the mathematics classroom. One such way that students can enhance their problem-solving skills is by asking students to both solve a math word problem and explain their thinking or problem-solving process in writing. This approach can be beneficial for teachers because "[w]hen students write explanations of their work and give examples, teachers can better assess student understanding and progress throughout time. Writing is an ideal vehicle for formative assessment, providing teachers with the information they need to adjust their instruction (Urqhart, 2009, p. 7). In order to demonstrate how this approach might be used in the classroom, teachers in the professional development session were led through a writing workshop, which was comprised of several best practices. In *Writing Next* (2007), a comprehensive analysis of research-based and effective strategies for teaching writing to adolescent learners, Graham and Perin (2007) identified 11 of the best strategies. Three of these strategies included studying sample/model responses, engaging in revising (peer review), and writing for content learning. These three strategies formed the basis for this math writing workshop.

Word Problem and Writing Prompt (Strategy 1)

First, the teachers provided with the following word problem/writing prompt; they were asked to compose a response that a 4th grade student might provide to this prompt: *Susan is building a fence for her dog in the shape of a square. She plans to make each side 12 feet long. She bought 50 feet of fencing. Does she have enough fencing for her project? Explain your answer.* Most teachers answered this prompt by writing, "Yes" or "Yes, she does." They explained that their middle grade students tend to write as little as possible. Even when they are told to explain their answers, their students still offer short responses.

Word Problem and Writing Prompt (Strategy 2)

Next, teachers were shown a revised version of the word problem/prompt: *Susan is building a fence for her dog in the shape of a square. She plans to make each side 12 feet long. She bought 50 feet of fencing. Does Susan have enough fencing for her project? Explain how you came up with your answer in one paragraph.* Teachers believed the revised prompt was more explicit; however, they were not sure if their students would understand precisely how to construct their response in paragraph form. The teachers were then presented three model answers to the word problem/writing prompt and were asked to choose the "best" response:

Model answer A: Yes, she has enough. Because she has 50 feet.

Model answer B: Yes, Susan has enough fencing. She has 50 feet and she needs 48 feet. I added each side of the square to find the perimeter (12+12+12+12 = 48). The perimeter of the square is 48 feet. 48 is less than 50, so she has enough fencing.

Model answer C: Yes, she has enough fencing. She needed 48 feet and she has 50 feet.

All teachers agreed that model answer B was the best response. As a whole group, teachers analyzed this response to determine the specific components of this paragraph that made it the "best" one. Together, they created the following writer's checklist to use when responding to word problem/writing prompts 1) Answer the question in a complete sentence, 2) Describe the steps you took to solve the problem, 3) Use math vocabulary (e.g., added, perimeter, and less than), 4) Restate your answer. By analyzing the model answers and developing a list of that answer's effective writing components, the teachers were engaging in the best practice, "study of models," as identified by Graham

Table 6: Peer Review Writing Workshop Form

Instructions: You will work with a partner. 1) Read aloud the paragraph you wrote in response to the prompt. 2) Ask your partner the questions in the 2nd column. 3) Write your partner's responses in the 3rd column. 4) Complete the same peer review process with your partner's paragraph.

Writiing Trait	Ask Your Partner	Partner's Response
Idea: The purpose or message of the piece.	Did I answer the question in the prompt?	
Organization: The logic or structure of the piece.	Did I clearly describe all the steps I took to solve the problem, or is there missing information/steps?	
Word Choice: The vocabulary/ language a writer uses.	What are some examples of vocabulary or academic language that I used in my paragraph?	
Conventions: Use of grammar, mechanics, spelling, and punctuation.	Where are places that I need to correct spelling, grammar, or punctuation?	

and Perin (2007).

Word Problem and Writing Prompt (Strategy 3)

Teachers were then given a second opportunity to take on the persona of a middle grades student writer and compose a response to a second word problem/writing prompt. This time, the teachers were told to use their writing checklist as they composed their response to this prompt: *Mike has 25 feet of fencing. He plans to make a fence for his dog in the shape of a rectangle. The fence will be 10 feet long and 5 feet wide. Does Mike have enough fencing for his project? Explain how you came up with your answer in one paragraph.* After completing their responses, teachers worked with a partner to conduct a peer review workshop on one another's writing. Teachers used the peer review workshop form, displayed in Table 6.

The teachers explained that completing the second writing prompt activity was much easier than completing the first prompt activity. They noted that it was easier to write a detailed response to the prompt when that prompt explicitly asked for them to explain how they devised their answer to the math problem. Additionally, they commented that seeing the sample responses and developing the writer's checklist helped them better envision what their paragraph should look like. Finally, they liked participating in the peer review workshop because it allowed them the opportunity to see how others structured their paragraphs and to discuss their mathematical thinking. By participating in the peer review activity, the teachers were experiencing another best practice, as identified by Graham and Perin (2007): the revision process. Finally, as teachers engaged in the full sequence of instructional activities – from analyzing writing prompts, to analyzing model answers, to developing a writer's checklist, to composing a response, and to reviewing/revising their response – teachers engaged in a third best practice: writing for content learning (Graham & Perin, 2007).

Summary of Workshop Results

A second purpose of this article was to examine the perceptions of middle grades mathematics classroom teachers regarding the NCTM (2000) principle, which states that "students who have opportunities, encouragement, and support for writing, reading, and listening in mathematics classes reap dual benefits: they communicate to learn mathematics, and they learn to communicate mathematically" (p.60). That is, what connections (if any) did teachers notice regarding students' literacy achievement and mathematical

Table 7: Survey Results

Pre-Survey and Post-Survey Questions	Strongly Agree (SA)	Agree (A)	Neutral (N)	Disagree (D)	Strongly Disagree (SD)
Pre-Survey Students who read and write well are usually successful in mathematics.19% responded A.	0 0%	3 19%	5 31%	6 38%	2 12%
Post-Survey **Students who read and write well are usually successful in mathematics. 37% responded SA or A.**	1 6%	5 31%	6 38%	4 25%	0 0%
Pre-Survey Students can have very strong mathematical skills and still be poor readers and writers. 88% responded SA or A.	6 38%	8 50%	1 6%	0 0%	1 6%
Post-Survey **Students can have very strong mathematical skills and still be poor readers and writers. 94% responded SA or A.**	5 31%	10 63%	1 6%	0 0%	0 0%
Pre-Survey I can recall certain students that appear to have proficient math skills but underperform in solving mathematical word problems. 88% responded SA or A.	7 44%	7 44%	1 6%	0 0%	1 6%

achievement? Teachers completed a pre-survey and post-survey; their responses are as follows in Table 7.

In both the pre-survey and post-survey, fewer than half of the teachers believed that students who read and write well are usually successful in mathematics. In fact, only 19% agreed or strongly agreed with this statement in the pre-survey, and 37% agreed or strongly agreed in the post-survey. Similarly, nearly all teachers agreed or strongly agreed that students could have strong mathematical skills and poor reading or writing skills. Therefore, teachers did not perceive a strong link between students' literacy proficiency and math content proficiency.

Next, teachers were asked to reflect upon their actual classroom experiences. In response to a pre-survey item, 88% of teachers said they agreed or strongly agreed to the statement, "I can recall certain students that appear to have decent math skills but underperform in solving mathematical word problems." Thus, the majority of teachers admitted to having worked with students who seemed to struggle, in particular, with word problems despite possessing otherwise competent content knowledge. According to new standards recently implemented at the national and state levels, students must demonstrate more than procedural fluency in mathematics. That is, students must be able to comprehend complex word problems and communicate their understanding orally and in writing (National Governors Association & Council of Chief State School Officers, 2010; Georgia Department of Education, 2015). According to these standards, students must "think critically" to create "reasoned, logical connections" as they solve problems (GADOE, 2015, p. 2). To do so, students will need to possess the necessary reading and writing skills. In turn, teachers must be equipped with strategies to assist students in both mathematics and literacy instruction.

The third purpose of this article was to determine the impact or lack thereof of the professional development in the teachers' classrooms. Teachers completed pre- and post-surveys in which they identified their understanding and use of literacy instructional strategies within their classrooms and reported on their knowledge gained from the workshop sessions. Survey results are as follows in Table 8.

Although 75% of the teachers responded that they currently use reading and writing strategies to teach

Table 8: Professional Development Impact Survey

Pre-Survey and Post-Survey Questions	Strongly Agree (SA)	Agree (A)	Neutral (N)	Disagree (D)	Strongly Disagree (SD)
Pre-Survey Currently I use reading and writing strategies to help teach my students mathematics.75% responded SA or A.	2 12%	10 63%	3 19%	1 6%	0 0%
I am confident in selecting appropriate reading andwriting strategies for my students to use in studying mathematics. 50% responded SA or A.	1 6%	7 44%	6 38%	1 6%	1 6%
I can list at least 4-6 reading strategies that target teaching mathematics. 6% answered SA.	1 6%	0 0%	10 63%	4 25%	1 6%
I can list at least 4-6 writing strategies that target teaching mathematics. 12.5% answered SA.	2 12.5%	0 0%	9 56%	3 19%	2 12.5%
Post-Survey **I understand and can list some of the reading strategies presented that target developing mathematical literacy. 100% responded SA or A.**	**7** **44%**	**9** **56%**	**0** **0%**	**0** **0%**	**0** **0%**
I understand and can list some of the writing strategies presented that target developing mathematical literacy. 100% responded SA or A.	**7** **44%**	**9** **56%**	**0** **0%**	**0** **0%**	**0** **0%**

students mathematics in the pre-survey, only 50% of teachers reported that they were confident in selecting appropriate reading and writing strategies. Prior to participating in the reading and writing professional development sessions, merely 6% could list four reading strategies and 12.5% could list four writing strategies. The pre-survey data, then, indicated that many of these middle grades teachers lacked knowledge of reading and writing strategies as well as the confidence for selecting and using such strategies in their classrooms, particularly with students who struggle with understanding the content material.

Table 9: Final Project Evaluation

#	Item	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	During Fall 2015, I implemented some of the ***reading*** strategies presented during the Summer Reading Workshop that targeted developing mathematical literacy through reading.					
2	During Fall 2015, I implemented some of the ***writing*** strategies presented during the Summer Writing Workshop that targeted developing mathematical literacy through writing.					
3	Students who read and write well are usually successful in mathematics.					
4	Students who do not read and write well are not usually successful in mathematics.					

Following the professional development sessions, the post-survey results reflected that 100% of the teachers could list some of the reading and writing strategies. Yet, understanding how to use a strategy hypothetically and actually implementing that strategy in one's classroom are two distinct tasks. To determine to what extent the reading and writing professional development sessions impacted teachers' real-world instructional practices, a follow-up survey was emailed to each of the summer teachers during fall semester (see Table 9). None of the teachers chose to participate in this follow-up survey, which included the following items.

Additional open-ended questions included 1) If you implemented any of the reading strategies, which ones worked best for you and your students? 2) If you implemented any of the reading strategies, which ones worked best for you and your students? 3) What are some obstacles that have prevented you from teaching mathematics using research-based reading and writing strategies?

Article Findings and Next Steps

Pre-survey and post-survey results indicated that the majority of this article's teachers did not see strong connections between students' literacy and math skills, despite the fact that these teachers are being held accountable by new standards emphasizing literacy. As these teachers adapt their curricula and instruction to the newly adopted math and literacy standards, ongoing professional development will be needed to ensure all students receive adequate support.

In fact, the NCTM acknowledges the need for all educators to receive training in the new standards by recommending "[s]ubstantial opportunities for ongoing professional development" and by acknowledging that "systematic improvement takes a number of years" (2013, p. 60). This call for ongoing and "substantial" professional development echoes other scholarship regarding effective teacher development (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009, p. 21). That is, "[w]hile many teachers get a day or two of professional development on various topics each year, very few have the chance to study any aspects of teaching for more than two days" (Darling-Hammond et al., 2009, p. 20). As a result, these limited or one-time events may not significantly impact teachers' practices.

Clearly, teachers' survey responses indicate that taking part in one brief session did not allow them the time to gain in-depth knowledge of the literacy instructional strategies. Next, teachers were provided stipends for participating in the week-long series and in follow-up sessions focused on mathematics instruction. Their participation in completing the follow-up literacy survey and in implementing reading and writing strategies from the sessions was voluntary. Since none of the teachers completed the follow-up literacy survey, it is unknown as to what extent the teachers may have integrated strategies from the workshop into their classroom settings. As scholars (Darling-Hammond et al., 2009) have noted, "professional development is most effective when it addresses the concrete, everyday challenges involved in teaching and learning specific academic subject matter" (p. 10). Thus, it is recommended that future professional development series include follow-up sessions, preferably held during the academic year and focused specifically on the real-world challenges mathematics teachers face as they implement newly learned strategies.

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