Exploring the Use of Book Writing to Improve Student and PST Mathematics Understanding

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In this qualitative paper, the researchers utilized a modified rubric from Stein et al.'s (2017) work and investigated 26 children's book created by preservice elementary and middle school students. Using the modified rubric, the researches classified each of the 26 surface area themed books into 1 of 4 categories based on the storyline of the books. Sample student books and implications for teaching were discussed.

Keywords: children's literature, surface area, preservice teachers

INTRODUCTION

Students of all ages can struggle with mathematics and can often feel a disconnect to the mathematics being taught. Teachers must teach the content while making it meaningful for their students. Sherin et al. (2011) noted that children's mathematical thinking is important as they learn mathematics. Teachers need to anticipate the responses of their students during mathematics instruction and respond accordingly (Land et al., 2018). Students can respond in the form of writing letters to their teachers, authors, and fellow students (Sipka, 1990). The letters may be formal and informal. Students can describe a mathematics course or write a letter to the editor of their mathematics textbook.

For preservice teachers, Steele and Hillen (2012) proposed a plan whereby pedagogy was incorporated in a course focusing on mathematics content. They developed a variety of application problems for grades 2 to 12 that encompassed five representations: symbol, language, content, graph, and table. The authors of this article implement writing assignments that preservice teachers complete, which include the following: reviewing professional journal articles; planning an activity for 100 Days of School; maintaining a reflective mathematics journal that focused on course content; and writing and critiquing pen pal books.

This article is based on the last assignment, where preservice elementary (pre K-6th grade) and middle school (4^{th} to 8th grade) teachers wrote surface area themed children's books as part of a pen pal book exchange program with local middle school students. Each group was tasked with creating an original surface area themed book which concluded with a question that the reader would have to solve. The detailed specifics of the book project assignment can be found in an earlier published article (Wheeler et al., 2018). The purpose of this article involves an in-depth examination of the books from fall 2017 written by the PSTs using a modified version of Stein et al.'s (2017) work about teaching profiles.

LITERATURE REVIEW

Pen Pals in K-16 Classrooms

Throughout the literature, pen pals in the K-16 experience have been encouraged. Miller and England (1989) suggested that students should write to audiences other than their teacher since students generally found those scripts more valuable and interesting. Kurz (2011) noted that for preservice teachers, early exposure to school settings can enhance their educational growth and development. During our pen pal assignment, preservice teachers interacted with middle school teachers and students.

Writing projects can either have face-to-face interactions or be purely off-site. Phillips and Crespo's (1996) pen pal exchange included a face-to-face meeting toward the end of the university semester. The fourth-grade students wrote six letters, two of which were on designated topics. For the preservice teachers, the letter writing project was extra-curricular and did not count as credit in the mathematics methods course. One of the authors of this article incorporated a letter writing exchange between university elementary/middle school preservice teachers and sixth grade students. The preservice teachers wrote two letters explaining mathematics topics that were common to the university and sixth graders' course content. An introductory paragraph was included in the first letter. The sixth graders provided written feedback on the letters. Initially, the sixth graders visited the university campus but in subsequent semesters the visits were alternated between the university campus and the elementary school. When the sixth graders visited the university campus, they were given a tour of the campus by their writing buddies followed by mathematics games that the preservice teachers developed. Lampe and Uselmann's (2008) pen pal project also incorporated a face-to-face meeting at the end of the pen pal experience. During the semester, the elementary education majors exchanged an introduction letter and two sets of problems with middle school students. The middle schoolers critiqued the problems for level of difficulty, whether the problems were easy to understand, and what they liked or disliked about the problems. At the high school level, algebra students exchanged letters with preservice teachers on a weekly basis (Norton et al., 2009). The high school students were more engaged in learning mathematics and developing problem solving skills while the preservice teachers improved their skills in posing problems.

Writing in Mathematics

K-12 students, as well as pre-service and in-service teachers, are encouraged to write in the content areas. The Common Core State Standards for Writing promote writing across the K-12 curriculum (CCSSI 2010). Dusterhoff (1995, pp. 48-49) identified 6 reasons why students should write in mathematics:

1. Math topics and experiences provide interesting and challenging material about which to write.
2. Writing in mathematics increases mathematics learning.
3. General writing ability improves through writing in mathematics.
4. Writing can spark interest in the study of mathematics.
5. Writing helps students explore, clarify, confirm, and extend their thinking and understanding.
6. Writing helps the teacher access student learning and plan future instruction.

Burns (2004, p. 30) reiterated the fifth reason when she stated that writing in mathematics "requires students to organize, clarify, and reflect on their ideas." The NCTM's Principles and Standards for School Mathematics (2000, p. 60) stated that mathematics instruction should empower students to do the following:

- Organize and consolidate their mathematical thinking through communication.
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

- Analyze and evaluate the mathematical thinking and strategies of others.
- Use the language of mathematics to express mathematical ideas precisely.

These references support writing in mathematics. Brown and Masloski (2018) used written narratives with beginning secondary mathematics teachers. The teachers journaled about their classroom experiences with respect to climate, pedagogy, content, and management. Brown and Masloski found that contrary to past beliefs, the narratives of the teachers focused on the content and the teaching of mathematics rather than on classroom management. As teachers write in their mathematics education courses, they are encouraged to include writing in the mathematics instruction.

The English Language Arts (ELA) standards identify three types of writing: arguments, informative/explanatory texts, and narratives (CCSSI, 2010). This project focuses on the latter two that require students to follow a multistep procedure as they read books and solve problems or create books that include problems. This is in line with Casa's (2014) suggestion that authoring word problems and written discourse are examples of writing tasks that promote mathematical reasoning.

Mathematics word problems can be phrased so that they relate to students' experiences. Overholt et al.'s (2008, p. ix) book includes "problems that are interesting, true-to-life situations". The problems include a real-life narrative, an illustration, and sets of problems that encourage students to use problem solving skills, such as physical representation, draw a diagram, and make a list. When a teacher was developing formulas with 4th grade students, she related the formulas to the students' reading curriculum (Battey, 2013). Given the reading rate, students calculated how many pages they had read. Students related mathematics problems to familiar experiences. When students were writing equations, they suggested using a box to represent the variable. This provided the teacher with an opportunity to introduce variables instead of boxes.

Although the mathematics content of this project is for middle school, Casa (2016) noted that writing in mathematics can start in elementary school. When elementary students received mathematical writing instruction, they were more capable of writing quality texts that included mathematically appropriate vocabulary and representations.

Mathematics and Art

As students write in mathematics, they may include illustrations to complement the mathematical computations. Draw a diagram or sketch is a common strategy mathematics teacher encourage students to implement as they solve problems. This skill can be extended when students author their own books. They can draw illustrations that match the narrative. Students who are less apt to solve mathematics projects but are artistically inclined may then be keen to participate in the writing project. They can draw the illustration to match the narrative. Art-integration is a term used when art is merged with another discipline as a way of promoting "inclusiveness in teaching, learning, and experiencing" (LaJevic, 2013, p. 2). Art examples with implications for mathematics that LaJevic includes are paper snowflakes that portray symmetry and a clock constructed from a paper plate. LaJevic's Appendix includes implications for art across Language Arts, Mathematics, Science, and Social Studies. The mathematics section is outlined according to Objectives, Content, Procedures for Measurement, Reteaching Activities, and Enrichment Activities. The last two sections reflect skills students demonstrate in mathematics writing projects, using pictures, and creating student-made activities for class presentations. Columba, Kim, and Moe (2009) noted that when mathematics and other subject matters are integrated, learning becomes connected. They authored a book that includes over fifty lessons that integrate mathematics, science, and social studies for Pre-Kindergarten-8. Likewise, Ward's (2009) book includes lessons that integrate literature, mathematics, and visual arts for grades 3-5. There are also suggestions of how to incorporate science and social studies for cross curricular connections.

Lau (2014) integrated art during mathematics instruction in four lessons with first grade students. In the first lesson, students created jack-o-lanterns and glued addition strips on them. For the second art activity, Lau incorporated doubles in the *Neighbors Art Project*. Using 3 paper houses, students labeled

one with a doubles addition fact and the other two with related addition problems, (e.g., 6 + 6 would have neighbors 5 + 6 and 6 + 7). For the third project, students created a turkey and used colors on the turkey to create patterns, (e.g., an AB pattern could be red, blue, red, blue, red). The last lesson was the *Santa Cookie Math Problem*. Students created a problem modeling subtraction, (e.g., How many cookies were on the plate at night? How many remained the next morning? How many cookies did Santa eat?). Before the art in mathematics project, 6 of the 20 students responded that art is related to mathematics. After the intervention, 10 of the students saw the relationship between art and mathematics. At the upper elementary and middle school levels, Kurz and Bartholomew (2013) incorporated art as students wrote and illustrated books portraying a mathematics concept. Students developed their books using PowerPoint slides.

Teaching K-12 mathematics and mathematics education courses should not be seen in isolation. The two levels can complement each other with preservice students learning from K-12 students and vice versa.

ASSESSMENT TOOL

Using an "a priori, content-specific scheme" (Schwandt, 2001, p. 26) for coding, the researchers modified Stein et al.'s (2017) matrix of teaching profiles. In Stein et al.'s work, the authors discuss how teaching is more than just two classifications, procedural and conceptual fluency. Rather, there are four distinct categories of teaching profiles that demonstrate the interplay of the explicit attention to concepts (EAC) and students' opportunity to struggle (SOS) discussed in the theoretical framework of Hiebert and Grouws (2007).

EAC refers to student learning during teaching. Student learning can vary dramatically from high EAC with deep, conceptual learning of concepts to low EAC with procedurally driven tasks. SOS refers to how difficult activities are for the students. Like EAC, SOS varies from high SOS problems, where students may struggle to answer a thought-provoking task, to low SOS problems that require little thought to reach an answer.

With Stein et al.'s work, they propose a four-quadrant matrix to describe teaching. This matrix takes into consideration not only the two most familiar forms of teaching, Quadrant 1's standards-based instruction (NCTM, 2000) and Quadrant 4's procedurally driven instruction but adds two additional quadrants. Quadrant 2 instruction involves teaching with conceptually-rich tasks (high EAC) where the teacher has given the students so much information that the problem has been reduced to very little, if any, original thought to arrive at an answer (low SOS). The teacher explains the process or procedure at arriving at the answer so that the teaching is more valuable than a strictly formula-driven lesson. Quadrant 3 (low EAC and high SOS) teaching scenarios involve open-ended tasks where there is a disconnect between the problem and the student knowledge. Students may not have the necessary information and/or mathematical background to complete the problem.

For this study, the researchers were examining the work of PSTs, not specifically observing instruction. Thus, the researchers modified the original matrix to form Figure 1 that examines 26 children's books written by PSTs, where the researchers treated the authors of the children's books as the instructors of the content of the books.

FIGURE 1
A MODIFIED MATRIX OF STEIN ET AL.'S (2017) WORK USED FOR THIS STUDY

Quadrant 1: A high quality (conceptually based) task where readers have productive struggle to determine the solution. The book includes a thought-provoking problem, where the reader must think critically about the information given to be able to be successful with the problem. In addition, the task given is often a multi-step, multi-dimensional problem.	**Quadrant 2:** A low quality (procedurally based) problem, where the authors try to make connections for the readers to the formula(s) given.
Quadrant 3: A high quality (conceptually based) problem, but the reader does not have the necessary background information/knowledge to successfully solve the problem. The problem is challenging, but there is some disconnect between what the author wants the reader to do and what can be accomplished with the given information.	**Quadrant 4:** A low quality (procedurally based) problem where the reader does not need to think for himself/herself to complete the task. It is a problem where the reader substitutes into a formula to arrive at an answer without any connections to why the procedures work. You do not have to fully understand the problem to calculate the solution.

The books were then examined to see at what level of EAC and SOS the books were intended to elicit from readers.

Based on the modified matrix, Quadrant 1 books consisted of books that included a challenging problem, where the readers of the book would often struggle to arrive at the answer. Often, these books included multi-step problems with no straightforward answer. Quadrant 2 books consisted of books that originally had a low quality (procedural) problem, but the authors tried to explain the concept of surface area and the formulas to be used. Like Quadrant 1 books, Quadrant 3 books consisted of thought-provoking tasks but with a disconnect for the reader. The reader would not be able to solve the task because of some form of missing information and or misleading picture(s). Lastly, Quadrant 4 books included a basic problem to solve, where the authors often gave the reader the formula and no thought was given as to why the formula worked.

RESEARCH QUESTION

Using the modified matrix as an assessment tool for the study, the researchers answered the following research question:
What types of children's books about surface area were created by elementary and middle school PSTs?

METHODOLOGY

Participants and Setting

The participants for this research consisted of 2 classes of future elementary (pre-K to 6th grade) and middle school (4th to 8th grade) teachers at a university in the south-central United States. The three-credit hour freshman course was designed to teach standards-based mathematics content and pedagogy at the 6th to 8th grade level. One of the researchers was the teacher of the course. For this study, the two researchers examined children's books of 26 PSTs from fall 2017. The researchers detailed their book project in a previous manuscript (Wheeler et al., 2018), which was based on the work of Kurz and Bartholomew (2013) (see Figure 2 for a summary of the project guidelines).

FIGURE 2
ASSIGNMENT DETAILS

Make a Google Slide or PowerPoint children's book that covers a **surface area middle school mathematics standard**. You may choose from either the 7th grade or 8th grade surface area standard.

For your book, you will need to include a title page with your name, a slide with the mathematical standard your book covers, and at least 6 more pages of text. Each page of your children's book must contain text and original photographs. The last page of your text should include a grade appropriate surface area problem. You must also turn in a solution to your problem.

Future teachers could work by themselves or work in groups of up to 4 total members. Of the 26 books written by PSTs, 13 students chose to work by themselves, and 13 chose to work in groups.

Coding

Coding consisted of both researchers independently examining the books and classifying each book into 1 of the 4 quadrants using the modified version of the Stein et al.'s (2017) rubric. Through the coding process, two books were excluded. One of the PST books covered the topic of volume instead of surface area, while the other excluded book did not have an overarching question to be answered, which was a requirement of the assignment. After initial coding, the two researchers compared codes and came to a 100% agreement on any discrepancies.

FINDINGS

Table 1 is a summary data for the books subdivided by quadrants.

TABLE 1
SUMMARY DATA FOR THE BOOK PROJECT

	Preservice Teachers (n = 24)	Frequency
Quadrant 1	6	25%
Quadrant 2	2	8.3%
Quadrant 3	4	16.7%
Quadrant 4	12	50%

Quadrant 4 Books

As can be seen from Table 1, the most popular category of book was Quadrant 4, the procedurally driven books. Authors often set up a basic surface area problem, where readers could substitute into a formula and arrive at answers with no thought as to what the surface area formula meant. A typical Quadrant 4 example is described below with the PST book entitled *Geocache Surface Area.*

In *Geocache Surface Area*, a group of 4 students have decided to try geocaching, scavenger hunting with a Global Positioning System (GPS) device and want to hide a cylindrical canister (see Figure 2). They enlist the reader's help to determine the amount of duct tape needed to wrap the entire canister.

FIGURE 2
GEOCACHE CANISTER BEING HID IN THE BUSH

This type of problem is basic with the reader needing to substitute the given information into the surface area formula for a cylinder. There was no explanation of the formula nor why the formula worked.

Quadrant 3 Books

The third most common type of book was Quadrant 3 books. Books from Quadrant 3 included books with a challenging problem for the reader, but there was some issue with the problem to where the reader would not be able to solve the problem with the given information. Typically, these books included misleading pictures and/or missing information so that the reader could not successfully arrive at any answer. As an example of a typical Quadrant 3 book is entitled *What's in the Box*. In the story, a boy is wanting a dinosaur for Christmas. He sees his different Christmas presents but wonders if his dinosaur could be inside. He decides to measure his friend's dinosaur and then measure his presents (see Figure 3).

FIGURE 3
THE DINOSAUR AND ONE OF THE WRAPPED PRESENTS

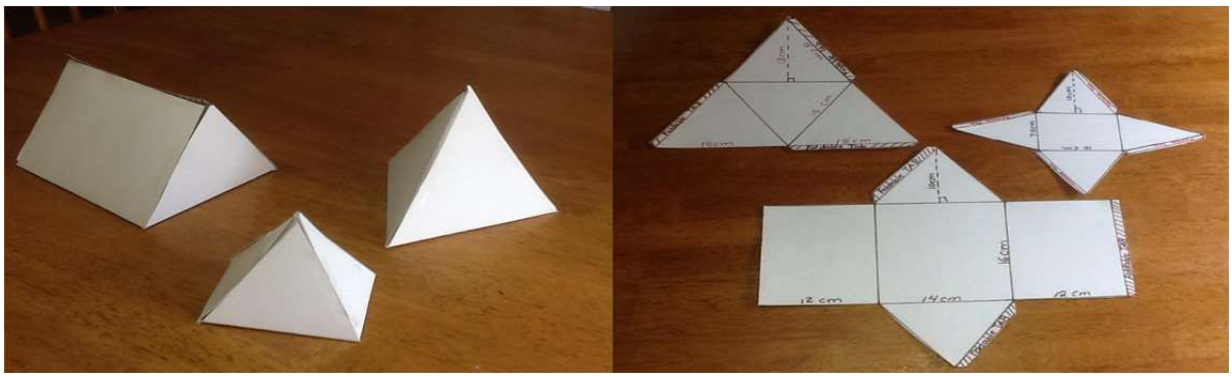
The book ends with the measurements of the presents. The PST never actually asks a question to the reader, so the reader does not know what to do with the information.

Quadrant 1 Books

Quadrant 1 included the most conceptually driven themed books of the four quadrants. Participants created books that had a challenging problem that often-included multiple steps with no straightforward answer. *The Colorful Solution* is an example text from the PST group that exemplifies these books.

In *The Colorful Solution*, a child named Andrew and his family sell taffy at the state fair. Andrew thought that having his family sell their taffy in boxes shaped like pyramids or triangular prisms might be more interesting than their typical boxes that were rectangular prisms. Andrew's father purchased three different boxes, but the family decided to cover them with wrapping paper to make them more interesting. The culminating problem was to determine how much paper would be needed to cover 1,000 boxes of each of the 3 solids (see Figure 4).

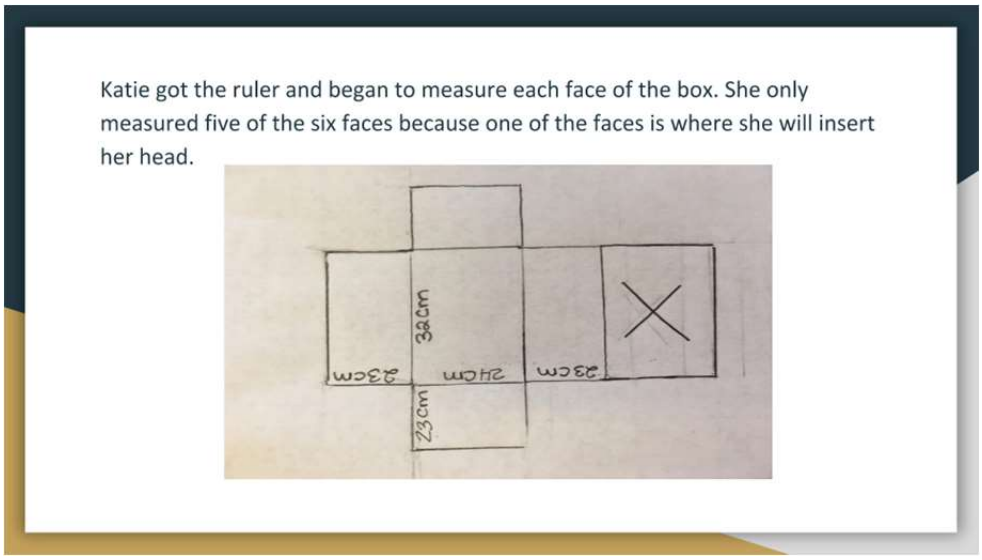
FIGURE 4
THE CANDY BOXES USED IN THE *COLORFUL SOLUTION*



Quadrant 2 Books

The least popular category of book for PSTs was Quadrant 2. For Quadrant 2 books, authors created books that were procedurally driven, but the authors always explained the surface area formulas to the reader. An example of a Quadrant 2 book came from the PST book entitled *Get Creative with Me!* In the book, the authors describe how a girl named Katie is needing your help to make a robot costume for a science convention. Instead of leaving it to the reader to decide which sides of a box need to be covered for the head of the robot, the authors tell the readers to only use 5 of the six faces, as well as they draw a net of the box (see Figure 5).

FIGURE 5
A SAMPLE OF A QUADRANT 3 BOOK WITH A LABELED NET



Thus, a problem that could potentially have been classified as a Quadrant 1 problem has been reduced to a Quadrant 2 problem. The researchers did not label it as a Quadrant 4 problem because the authors did try to explain how surface area worked within the context of the problem.

DISCUSSION

The findings suggest that future teachers can write children's books about surface area at varying levels of EAC and SOS. It is not surprising that PSTs created more procedurally driven (Quadrant 4) books than any other type of book. These types of books required the least amount of effort and understanding for the participants to make. The PST class included students who were either seeking elementary (Pre- Kindergarten-6th) or middle school (4-8th grade) certification. Surface area, the topic of the book, is a 7th and 8th grade topic in the state under study. Often, preservice teachers in that course struggle with the concept of surface area so creating a book which is of less cognitive demand may also be because of the difficulty of the topic.

To help the PSTs create books at higher EAC and SOS levels, PSTs could analyze books at various EAC and SOS levels as a way to orientate the future teachers with what constitutes books in all four quadrants. They also could even be given various books, as well as the researcher's modified matrix, to try to revise the books to make them at higher EAC and SOS classifications. After these two rounds of activities with class discussions, PSTs could be tasked with creating their own books. Similar rounds of assignments have been given to other preservice teachers (Sherman et al., 2018) coupled with *The Mathematical Tasks Framework* (Stein & Smith, 1998) that showed encouraging findings for preservice teachers being able to successfully make high-level activities.

IMPLICATIONS FOR TEACHING

Based on the study, the researchers feel that having PSTs create children's books can be a challenging but rewarding activity. PSTs must research the given mathematical standard and try to create a real-world task that not only makes sense but hopefully is challenging to the reader.

University instructors who want their PSTs to have a unique experience of researching real world applications of a mathematical standard, as well creating a unique storyline that might engage students of

a certain age, might enjoy giving such a task to their classes. In written reflections, the future teachers commented about the book project and its usefulness for her future career. The following future teacher summarized a common theme among many of the future teachers, which included anxiety about the assignment but overall a rewarding experience they could potentially incorporate into their own class:

> Honestly, at first, I was indecisive of how I felt about the project when it was initially introduced to our class because it just seemed extremely stressful in addition to everything else we have going on with this course. When my group first started the project, it seemed like it was extremely impossible to accomplish as well as some of our group members weren't on the same page as the rest of the group, which made it a bit difficult...Although, once I got in the groove of the project itself, it became fun and it made me excited to be creative about it. I'm extremely excited to see what the students think of our book because we put a lot of hard work into it. Also, I'm excited to see how much they loved our Billy Willis Timmy Jr.'s hunt to find the donut box and see how creative they were with their books. In conclusion, I ended up loving the project because it was such a unique project that I could possibly incorporate within my future classroom.

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