SSMA 2017 Proceedings - Volume 4



116th Annual Convention November 2 - 4, 2017 Lexington, Kentucky

Margaret J. Mohr-Schroeder Jonathan Thomas Editors

PROCEEDINGS OF THE 116TH ANNUAL CONVENTION OF THE SCHOOL SCIENCE AND MATHEMATICS ASSOCIATION

November 2 – 4, 2017 Lexington, KY, USA

Editors: Margaret J. Mohr-Schroeder & Jonathan N. Thomas

Cite Proceedings Volume as:

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

Cite Proceedings Chapter as:

Author. (2017). Title of chapter. In M. J. Mohr-Schroeder, & J. N. Thomas (Eds.), *Proceedings of the* 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

Website: www.ssma.org

The proceedings are also available via http://www.ssma.org/convention-proceedings

Copyrights © 2017 left to the authors

Articles published in the Proceedings are copyrighted by the author. Permission to reproduce an article or portions from an article must be obtained from the author.

All rights reserved

ISBN: 978-1-5323-8631-2

SSMA 2017 CONVENTION: LEXINGTON, KENTUCKY

SSMA Leadership

President, Stacy Reeder, University of Oklahoma, 2016-2018 Past-President, Gil Naizer, Texas A&M University – Commerce, 2016-2018

Co-Executive Directors and Convention Chairs

Melanie Shores, University of Alabama Birmingham, 2014-2019 Tommy Smith, University of Alabama Birmingham, 2014-2019

Directors-at-Large

Charles Emenaker, University of Cincinnati Blue Ash, 2014-2017 Elaine Tuft, Utah Valley University, 2014-2017
Margaret Mohr-Schroeder, University of Kentucky, 2015-2018 Ken Miller, Montana State University, 2015-2018 Toni Ivey, Oklahoma State University, 2016-2019 Christa Jackson, 2016-2019

School Science and Mathematics Journal Editors

Carla Johnson, Purdue University, 2011-2021 Shelly Harkness, University of Cincinnati, 2011-2021

Newsletter Editor

Georgia Cobbs, University of Montana, 2016-2018

2017 Program Chairs and Local Arrangements Chairs

University of Kentucky Department of STEM Education Lisa Amick, Brett Criswell, Molly Fisher, Cindy Jong, Rebecca Krall, Margaret Mohr-Schroeder, Jonathan Thomas, Jennifer Wilhelm

Proceedings Editors

Margaret Mohr-Schroeder & Jonathan Thomas University of Kentucky



School Science and Mathematics Association Founded in 1901

The School Science and Mathematics Association [SSMA] is an inclusive professional community of researchers and teachers who promote research, scholarship, and practice that improves school science and mathematics and advances the integration of science and mathematics.

SSMA began in 1901 but has undergone several name changes over the years. The Association, which began in Chicago, was first named the Central Association of Physics Teachers with C. H. Smith named as President. In 1902, the Association became the Central Association of Science and Mathematics Teachers (CASMT) and C. H. Smith continued as President. July 18, 1928 marked the formal incorporation of CASMT in the State of Illinois. On December 8, 1970, the Association changed its name to School Science and Mathematics Association. Now the organizational name aligned with the title of the journal and embraced the national and international status the organization had managed for many years. Throughout its entire history, the Association has served as a sounding board and enabler for numerous related organizations (e.g., Pennsylvania Science Teachers Association and the National Council of Teachers of Mathematics).

SSMA focuses on promoting research-based innovations related to K-16 teacher preparation and continued professional enhancement in science and mathematics. Target audiences include higher education faculty members, K-16 school leaders and K-16 classroom teachers.

Four goals define the activities and products of the School Science and Mathematics Association:

- Building and sustaining a community of teachers, researchers, scientists, and mathematicians
- Advancing knowledge through research in science and mathematics education and their integration
- Informing practice through the dissemination of scholarly works in and across science and mathematics

Influencing policy in science and mathematics education at local, state, and national level

PREFACE

These proceedings are a written record of some of the research and instructional innovations presented at the 117^{th} Annual Meeting of the School Science and Mathematics Association held in Lexington, Kentucky, November 2 – 4, 2017. The blinded, peer reviewed proceedings includes 8 papers regarding instructional innovations and research. The acceptance rate for the proceedings was 89%. We are pleased to present these Proceedings as an important resource for the mathematics, science, and STEM education community.

Margaret J. Mohr-Schroeder Jonathan N. Thomas Co-Editors

TABLE OF CONTENTS VOLUME 4

Unpacking Teachers' Attitude toward Mathematical Modeling: Implications for Teacher Education and Professional Development
Reuben S. Asempapa.
A Computer tool that will allow secondary science teachers to differentiate reading materials for students with varied reading abilities
Wanjing Ma
Looking Beyond Graphical Representations with Transnumeration22
Michael Daiga
Supporting STEAM Practices with Digital Notebooking29
Bridget Miller & Christie Martin
Perspectives Change on STEM Integration: Or do They?
Melanie Fields, Christina Regian, Becky Sinclair, & Gilbert Naizer
Developing Preservice Teachers' Understanding of Effective Mathematical Teaching Practices Using Vignettes
Keith Kerschen, Ryann Shelton, & Trena L. Wilkerson
Enriching Prospective Teachers' Understandings of Area: Addressing Preferences for Boundedness and Resemblance
Michelle T. Chamberlin
Delijah's story: overcoming boredom and remediation to maintain a positive mathematics identity60
Thomas Roberts

UNPACKING TEACHERS' ATTITUDE TOWARD MATHEMATICAL MODELING: IMPLICATIONS FOR TEACHER EDUCATION AND PROFESSIONAL DEVELOPMENT

Reuben S. Asempapa Penn State Harrisburg rsa26@psu.edu

This paper presents an evaluation of a quantitative tool to assess teachers' attitudes toward mathematical modeling. Based on responses from 62 teachers of mathematics, the scale was evaluated using exploratory factor analysis and other psychometric properties. The scale isolated four dimensions: constructivism, understanding, relevance and real-life, and motivation and interest. These four factors accounted for 70.2% of the variation in the 28–item measure. The overall Cronbach's coefficients alpha for the scale was .96. The findings suggest a psychometrically valid and reliable scale for studying teachers' attitude toward mathematical modeling and have implications for teacher education and future research.

Introduction

This study investigated teachers' attitude toward and experiences with mathematical modeling. With the increased importance in modeling (NGA Center & CCSSO, 2010; NGSS Lead States, 2013), it is important to have an understanding of teachers' attitude toward mathematical modeling. Most teachers of mathematics have misconceptions about mathematical modeling (Gould, 2013; Spandaw & Zwaneveld, 2010; Wolfe, 2013) and lack knowledge of mathematical modeling (Blum, 2015). In most cases, teachers are the key to effective implementation of new standards, and modeling is no exception. Given that teachers have tremendous potential to transmit beliefs, values, and attitudes to students, it is essential to understand the attitude that teachers' hold about mathematical modeling education and what variables influence this attitude.

First, this paper addresses mathematical modeling and teachers' attitude, noting the effect of teachers' attitude on students' success and learning. Second, the paper discusses the phases used in developing the scale and describes the methods used to collect data. Third, the paper provides scaling results, and validity and reliability evidence from a pilot study. Finally, the paper concludes with implications for teacher preparation programs and professional development in relation to mathematical modeling education.

Purpose of the Study

Mathematical modeling strongly influences what mathematics students learn and how they learn it. This study highlights claims that teachers' attitude in general plays a significant role in their teaching profession. Teachers' attitude toward mathematical modeling influences students' mathematical behavior inside and outside the classroom, and their willingness to see the utility and relevance of mathematics. Through mathematical modeling, students learn different mathematical concepts and practices. Researchers, standards, and reports emphasize the need for teachers to address the skills and understanding of mathematical modeling in the teaching and learning of mathematics (Blum, 2015; Blum & Borromeo Ferri, 2009; COMAP & SIAM, 2016; Lesh, 2012; NCTM, 2009; NGA Center & CCSSO, 2010)

The attention of recent research and assessment tools in mathematical modeling have focused on teachers' conceptions and knowledge rather than attitude (Asempapa, 2016; Gould, 2013). Some progress have been made in the development of individually administered tools to ascertain teachers concerns regarding mathematical modeling (Wolfe, 2013). The purpose of this study was to produce a public-domain instrument that would remedy these shortcomings and enable both researchers and educators to estimate attitude toward mathematical modeling efficiently and reliably. Therefore, this paper presents that instrument along with discussions of its development, and implications for its use and teacher education.

Significance and Related Literature

Mathematical modeling is more than simply presenting students with traditional word problem. Mathematical modeling provides much more "powerful and effective ways to help students become (a) better problem solvers, and (b) better able to use mathematics in real life situations beyond school" (Lesh, 2012, p. 197). Studies have shown that mathematical modeling supports and motivates students' interest in mathematics (English & Watters, 2004; Pollak 2011). Research on teachers' attitude is motivated by the belief that attitude play a significant role in the teaching and learning of mathematics (Zan & Martino, 2007). Therefore, it was important to explore teachers' attitude toward mathematical modeling.

Research indicates that teachers' attitude toward mathematics have a substantial influence on mathematics teaching and learning and students' achievement (Zan & Martino, 2007). This suggests that teachers' attitude toward mathematical modeling is of the essence to help students develop mathematical skills and practices needed for the 21st century. It is important for teachers of mathematics to be aware of the significant impact and consequences their attitude toward mathematical modeling can have on student learning. Therefore, with the implementation of the Common Core standards (NGA Center & CCSSO, 2010) and the release of the GAIMME report (COMAP & SIAM, 2016), teachers' attitude toward mathematical modeling was worth investigating.

Methodology

Upon examination of several sources such as the Common Core, NCTM standards, and research articles (Blum & Borromeo Ferri, 2009; DeVellis, 2012; Fowler, 2014; Gould, 2013; Lesh, 2012; NCTM, 2009; NGA & Center, 2010; Pollak, 2011; Wolfe, 2013) an initial Mathematical Modeling Attitude Scale (MMAS) was developed with 60 items; formats of the items included a 6-point Likert scale from "strongly disagree" to "strongly agree" and questions related to teachers experiences with modeling. Using cognitive interviews, reviews with content experts and practicing teachers, as well as item analysis and factor analysis, the initial 60 items on the scale were modified and honed to a 28-item scale. The study employed a cross sectional descriptive survey research design as described by DeVellis (2012) and Fowler (2014). Purposeful sampling technique was employed to identify the participants who responded to this survey online. Of about 510 surveys distributed, 62 respondents fully completed this attitude scale, yielding about 12% response rate.

The main goal of the data analysis for the study was to have a valid and reliable scale that assesses teachers' attitude toward mathematical modeling. Survey data are only acceptable to the degree to which they are determined valid and reliable (DeVellis, 2012; Fowler, 2014). Hence, statistical procedures used to demonstrate the reliability and construct validity of the scale in this study included univariate analysis, Cronbach's alpha reliability analysis, and exploratory factor analysis (EFA). The SPSS statistical software was used for all the analyses. All analyses were considered statistically significant with p < .05.

Results and Discussion

In this study, the author answered two main research questions: (a) can the items included on the MMAS provide valid and reliable measures of teachers' attitude toward mathematical modeling? and (b) what are teachers experiences with mathematical modeling? The sample size for this study was n = 62. Descriptive statistics and demographic information were based on the 62 teachers. Of these 62 teachers, 77% of respondents were 35 years or older and almost 60% of the sample were identified as White or Caucasian. Concerning gender, 85% of the sample self-identified as female, and 15% as male. Items on the MMAS were coded as 1, 2, 3, 4, 5, or 6, with "1" corresponding to "strongly disagree" and "6" for "strongly agree." Thus, grouping these scores into quartiles, the median score on the MMAS was computed to be 3.5.

Scores above 3.5 were considered as satisfactory or positive attitude and scores below 3.5 were deem as unsatisfactory or negative attitude toward mathematical modeling. Based on the data analysis, the overall total mean score on the MMAS was 4.72 (SD = 0.78), which showed that

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

teachers had a positive attitude toward modeling. A *t*-test was performed on the variable gender to find out whether there was any difference between male and female teachers' attitude toward mathematical modeling. All the assumptions for conducting *t*-test was tenable, with Levene's test indicating equal variances (F = 1.82, p = .18). The *t*-test indicated the mean scores on the scale were not statistically significantly different for female teachers (M = 4.79, SD = 0.71) and for male teachers (M = 4.57, SD = 1.08), t(55) = 0.78, p = .44. Thus in this study and for this particular sample, the findings show that teachers of mathematics positive attitude toward mathematical modeling is equal regardless of their gender.

Another characteristic that was explored in this study was the variable grade level band. A one-way ANOVA was performed to determine whether there was a difference in teachers' positive attitude toward mathematical modeling based on their grade level band. The probability associated with Levene's test for equality of variance was F(2, 54) = .76, p = .47. Thus, the homogeneity of variance assumption was not violated indicating equal cell sizes of the groups. The one-way ANOVA showed that the mean scores on the scale were statistically significantly different for elementary school teachers (M = 4.97, SD = 0.66), middle school teachers (M = 4.45, SD = 0.76) and high school teachers (M = 4.44, SD = 0.86), F(2, 54) = 3.43, p < .05. However, Tukey's post hoc test for the individual pairwise *t*-test of any of the pairs of means yielded no statistically significant result.

The reliability and factor analysis of the MMAS scores were based on the 28 items on a 6point Likert scale. To the item reliability was determined by examining the correlation matrix between items and the item–total correlations. All 28 items were retained in the analysis because of their correlations ($r \ge .30$) and theoretical relevance (Nunnally & Bernstein, 1994; Osterlind, 2010). The overall internal consistency reliability of the MMAS for this sample was .96, indicating an acceptable reliable scale (DeVellis, 2012; Fowler, 2014). Table 1 provides information on the item– total correlations and alpha values on the MMAS. Exploratory factor analysis was performed to examine the interrelationships among items and examine the internal structure of the items on the MMAS. Although the sample size was relatively small, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of .75 and Bartlett's test with p < .05 were acceptable and supported factor analysis. The techniques used to select the number of emerging factors included (a) Kaiser's criterion for those factors with an eigenvalue greater than 1, (b) the Cattell's scree plot test, (c) cumulative percent of variance extracted, (d) factor interpretability and usefulness, and (e) parallel analysis.

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

Factor analysis was performed on three, four, and five, factors to explore how many factors could be extracted. Factor analysis revealed four independent factor structures and all the factor loadings were greater than .3, indicating that the items correlate well with the whole scale (Nunnally & Bernstein, 1994; Osterlind, 2010).

Table 1

Item	M	SD	ITC	α if item is deleted
Q1	4.72	1.36	.68	.964
Q2	4.96	1.18	.64	.964
Q3	4.89	1.17	.75	.963
Q4	4.65	1.32	.53	.965
Q5	4.78	1.20	.73	.963
Q6	5.02	1.05	.66	.964
Q7	4.33	1.08	.57	.964
Q8	4.59	1.00	.63	.964
Q9	4.63	1.12	.52	.965
Q10	4.93	1.16	.46	.965
Q11	4.37	1.08	.40	.966
Q12	4.74	1.13	.82	.963
Q13	4.80	1.13	.86	.962
Q14	5.06	0.99	.87	.963
Q15	4.91	1.10	.82	.963
Q16	4.70	1.17	.98	.964
Q17	4.91	1.18	.84	.962
Q18	4.83	1.07	.75	.963
Q19	4.43	1.17	.68	.964
Q20	4.93	1.00	.76	.963
Q21	4.85	1.05	.86	.962
Q22	4.19	1.19	.45	.966
Q23	4.43	1.17	.86	.962
Q24	4.65	1.06	.77	.963
Q25	4.61	1.12	.81	.963
Q26	4.52	1.09	.78	.963
Q27	4.46	1.07	.68	.964
Q28	4.20	1.18	.66	.964

Note: N = 62; ITC = item–total correlation.

Together these four-factor structures accounted for about 70.20% of total variance in the data set. The four-factors were labeled constructivism, understanding, relevance and real-life, and motivation and interest. Following the factor analysis, additional reliability analysis was conducted for each of the fourfactors using Cronbach's alpha coefficients. The six items under the factor constructivism had a reliability of .94 and five items under the factor understanding had a reliability of .81. The relevance and

real-life factor with seven items had a reliability of .95 and the *motivation and interest* factor had a reliability of .94 with 10 items.

In addition to the responses that the teachers provided regarding their attitude toward mathematical modeling, other information regarding their experiences with mathematical modeling practices were explored. This helped the researcher to assess teacher's perspectives and approaches to mathematical modeling practices, and get a sense of their experiences with modeling. Specifically, they were asked questions such as: Does your mathematics textbook have mathematical modeling activities? Did you take a mathematical modeling course in your teacher preparation? Table 2 provides complete descriptive information of the questions used to explore teachers' experiences on mathematical modeling in this study.

Table 2

Participants Experiences with Mathematical Modeling

Question	п	Yes (%)	No (%)	Not Sure (%)
Does your mathematics textbook have	61	19 (31)	25 (41)	17 (28)
mathematical modeling activities?				
Do you teach mathematical modeling activities?	62	40 (65)	5 (8)	17 (27)
Did you take a mathematical modeling course	62	6 (10)	48 (77)	8 (13)
in your teacher preparation program in college?				
Does your school district provide you with any	61	30 (49)	5 (8)	26 (43)
support in teaching mathematical modeling?				

Note: The variation in sample size is due to the variation in the number of responses

There were notable findings in examining teachers' responses on their experiences with mathematical modeling. Of the 61 teachers who responded to the question regarding whether they have modeling activities in their textbooks, only 31% of the teachers responded yes to this question. Most of the teachers' responses were that they do not have modeling activities in their textbooks and some did not have the specialized knowledge to identify mathematical modeling activities. Another area of concern was the question related to whether the teachers were exposed to mathematical modeling education during their teacher preparation program. About 77% of the teachers responded not having any training in mathematical modeling. Thus, most teachers from this study have limited experience with mathematical modeling, despite the usefulness and value in

demonstrating how mathematics can help analyze and guide decision making for real-world problems through mathematical modeling.

Conclusion and Implications

This study's goal was to develop, explore, and psychometrically assess a scale that assesses teachers' attitude toward mathematical modeling. Results from this study revealed that participants had a satisfactory attitude toward mathematical modeling. Given that the internal consistency coefficient of the scale was found to be .96, indicated that the scores from the scale were consistent with each other, and measuring the same construct–attitude toward mathematical modeling. Additionally, the results of item-total analysis demonstrated that the item-total correlations of the scale was acceptable and ranged from .40–.87. The reliability and validity evidence provided, as well as the psychometric properties of the MMAS demonstrates its potential in mathematics education research. Therefore, the MMAS can be used as part of ongoing evaluation of teachers' attitude toward mathematical modeling education.

Teachers' professional attitude toward mathematical modeling will enhance their teaching and learning of mathematics. Results from this study and other published materials (Kaiser, Schwarz, & Tiedmann, 2010; Spandaw & Zwaneveld, 2010) indicate a need exists for mathematical modeling training standards or courses to be integrated in teacher preparation programs for teachers of mathematics. Because there is no scale development study carried out with teachers of mathematics in related literature, the scale developed in this present study will bridge an important gap in studies related to mathematical modeling. It is hoped that the MMAS will benefit mathematics educators, researchers, and teachers, and advance mathematical modeling education in school mathematics.

References

- Asempapa, R. S. (2016). Developing an instrument to assess teachers' knowledge of the nature of mathematical modeling and their attitude toward such modeling. (Doctoral dissertation). Retrieved from http://rave.ohiolink.edu/etdc/view?acc_num=ohiou1458581416
- Blum, W. (2015). Quality teaching of mathematical modelling: What do we know, what can we do? In S. J. Cho (Ed.), Proceedings of the 12th International Congress on Mathematical Education: Intellectual and attitudinal challenges (pp. 73–96). New York, NY: Springer.
- Blum, W., & Borromeo Ferri, R. (2009). Mathematical modelling: Can it be taught and learnt? *Journal of Mathematical Modelling and Application*, 1, 45–58.
- Boaler, J. (2001). Mathematical modelling and new theories of learning. *Teaching Mathematics & Its Applications*, 20, 121-127.
- Consortium for Mathematics and Its Applications [COMAP] and Society for Industrial and Applied Mathematics [SIAM] (2016). *Guidelines for assessment and instruction in mathematical modeling education*. Retrieved from http://www.siam.org/reports/gaimme.php
- DeVellis, R. F. (2012). Scale development: Theory and applications. (3rd ed.). Los Angeles, CA: Sage.
- Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

- English, L. D., & Watters, J. J. (2004). Mathematical modelling with young children. In J. M. Hoines & B. A. Fuglestad (Eds.), *Proceedings of the 28th International PME Conference* (pp. 335–342). Bergen, Norway: Bergen University College.
- Fowler, F. J. (2014). Survey research methods (5th ed.) Thousand Oaks, CA: Sage.
- Gould, H. T. (2013). Teachers' conceptions of mathematical modeling. Retrieved from http://academiccommons. columbia.edu/item/ac:161497
- Kaiser, G., Schwarz, B., & Tiedemann, S. (2010). Future teachers' professional knowledge on modeling. In R. Lesh, P. L. Galbraith, C. R. Haines, & A. Hurford, (Eds.), *Modeling students' mathematical modeling competencies. ICTMA 13* (pp. 433–444). New York, NY: Springer.
- Lesh, R (2012). Research on models & modeling and implications for common core state curriculum standards. In R. Mayes, L. Hatfield, & S. Belbase, (Eds.), WISDOM^e Monograph: Quantitative reasoning and mathematical modeling. A driver for STEM integrated education and teaching in context, (Vol. 2, pp. 197–203), Laramie, WY: University of Wyoming.
- National Council of Teachers of Mathematics (2009). Focus in high school mathematics: Reasoning and sense making. Reston, VA: Author.
- National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). Common core state standards for mathematics. Washington, DC: Author. Retrieved from http://corestandards.org/assets/ CCSSI_Math%20Standards.pdf.
- Next Generation Science Standards Lead States. (2013). Next generation science standards: For states, by states. Washington, DC: National Academies Press.
- Nunnally, J. C., & Bernstein, I. H. (1994). Psychometric theory (3rd ed.). New York, NY: McGraw-Hill.
- Osterlind, S. J. (2010). Modern measurement: Theory, principles, and applications of mental appraisal. Upper Saddle River, NJ: Pearson.
- Pollak, H. O. (2011). What is mathematical modeling? Journal of Mathematics Education at Teachers College, 2, 64.
- Spandaw, J., & Zwaneveld, B. (2010). *Modelling in mathematics' teachers' professional development*. Paper presented at the Proceedings of the sixth Congress of the European Society for Research in Mathematics Education –Working group 11, (p. 2076–2085), Lyon, France: INRP.
- Wolfe, N. B. (2013). Teachers' understanding of and concerns about mathematical modeling in the common core standards (Doctoral dissertation). Retrieved from http://search.proquest.com.proxy.library.ohio.edu/ docview/1432193702?accountid=12954
- Zan, R., & Martino, P. D. (2007). Attitudes towards mathematics: Overcoming positive/negative dichotomy [Monograph]. Montana Mathematics Enthusiast, 3, 157–168.

A COMPUTER TOOL THAT WILL ALLOW SECONDARY SCIENCE TEACHERS TO DIFFERENTIATE READING MATERIALS FOR STUDENTS WITH VARIED READING ABILITIES

Wanjing Ma New York University wm821@nyu.edu

A challenge for the secondary science teacher is selecting written material that is appropriate for varying reading levels of their students. This paper presents a computer program (SCI-SCI-Reading) that is designed to help science teachers to tackle this challenge. By applying Natural Language Processing techniques to a corpus of 1800 science articles, this computer program is able to analyze selected text in terms of degree of difficulty of general academic language and degree of difficulty of specific scientific language to determine the appropriate reading grade level.

Introduction

A challenge for the secondary science teacher is selecting written material that is appropriate for varying reading levels of their students. Traditionally reading levels are determined by a formula: the Flesch-Kincaid looks at word length and sentence length, and the SMOG counts the number of polysyllabic words, etc. (Wellington & Osborne, 2001). However, this is not usually appropriate for science readings because there are also vocabulary considerations such as general academic language and specific scientific language that may vary from one grade level to another. In fact, the difficulty of science reading is unique. First, science text is difficult to read because of its high degree of "lexical density," the percentage of scientific words in relation to the total number of words in one text; and understanding the science behind those scientific words is the key to comprehend the text (Shanahan & Shanahan, 2008, p.53). Second, researches shows that words that are "non-technical but widely used for science" could be at least as problematic as scientific words (Wellington & Osborne, 2001, p.18). Third, academic words are widely used across the science texts; they are designed to be concise and authoritative, but may also be difficult to comprehend because they are not part of students' everyday vocabulary (Snow, 2010; Osborne et al. 2016). According to the challenges specific to science readings, a content-specific readability measurement tool is needed for science teaching.

NEWSELA, an increasingly popular instructional platform, is an attempt to provide teachers with current science reading materials that are adjusted to be appropriate for a wide variety of reading levels (https://newsela.com). Each science text set in NEWSELA is organized by a general science topic, and most of its articles are re-written versions of non-fiction science news from *Scientific American*, NASA.gov, and other press. The challenge is that the NEWSELA topics may not

always be aligned with the topics that are being studied in the science classes. SCI-SCI-Reading, the computer program developed in this study is designed to allow teachers to select a wider variety of reading materials that can be evaluated in terms of reading levels appropriate for the range of abilities needed in many secondary science classrooms.

Objectives of the Study

The first objective of this study is to explore whether the graded science articles from NEWSELA can become a reliable data source to represent the specific challenges in science reading. In other words, the study uses a corpus-based analysis, an analysis that uses collections of real life languages, to answer how well NEWSELA can be used to measure the readability of one science text based on context. If the graded NEWSELA articles are proved statistically to be representative of the specific challenges in science reading, then the next objective of this study is to develop SCI-SCI-Reading, a computer program that uses the NEWSELA data to estimate the readability of a wide range of science articles used in secondary school levels. Finally and more practically, this study aims to demonstrate how secondary science teachers can use SCI-SCI-Reading to analyze a selected text and access its difficulty for their students.

Theoretical Framework and Related Literature

Science education researchers pointed out that the traditional readability formulas are not helpful to access the difficulty of science reading, and they further suggested that teacher's own intuition is a more valuable tool for judging the readability (Wellington & Osborne, 2001). Appendix A of the Common Core State Standard (NGS & CCSSO, 2010c) provides detailed guidelines for choosing appropriate complex text, which includes both quantitative and qualitative measures. Besides teachers' own judgment, CCSS suggests teacher use *Lexile bands* as a reading tool to quantitatively measure the text complexity (Swanson & Wexler, 2017). Unfortunately, the current algorithm used by *Lexile Analyzer* is still based on sentence length and word familiarity and does not include scientific vocabulary. Although NEWSELA uses *Lexile bands* for reading grade determination, the graded NEWSELA articles have further value than what *Lexile bands* can indicate, because human experts' own intuition of the text complexity has been taken into consideration during the re-writing process.

Freed from the traditional readability formula, computer scientists started to treat the determination of the text complexity as a text categorization process (Collins-Thompson and Callan, 2005). Si and Callan from Carnegie Mellon University combined linguistic features with a statistical model to analyze a content-specific corpus including 91 K-8 science Web page passages; the result

showed this limited corpus achieved even a higher accuracy in measuring the text complexity than Flesch-Kincaid formula (2001). Their research confirmed a hypothesis that readability measurement incorporating the content text would be more accurate. The following study conducted by Collins-Thompson and Callan collected a larger and more diverse corpus including 550 documents with grade label K-12, and their statistical language modeling again proved to be effective in the readability determination (2005). They conceded that the size of their corpus was still small, and they were unsure about the reliability of the labeled grade they used for training. Nevertheless, they pointed out two helpful directions for improvement, which are used in SCI-SCI-Reading: (1) enlarging the corpus; (2) finding the grade-specific features.

So far, the best effort to evaluate the text complexity for education purpose as well as with the use of Natural Language Processing (NLP) techniques has been achieved by *TextEvaluator*, a text analysis tool developed by Educational Testing Service (ETS). ETS's corpus consisted of 1220 highly representative passages for education assessment purposes (Sheehan, 2016). Unlike the traditional measurement only focusing on word familiarity and syntactic complexity, *TextEvaluator* explored 6 additional language features by using NLP techniques. With more features taken into consideration, the correlation between the score of the text predicted by *TestEvaluator* and by human experts is high. However, since *TestEvaluator* was claimed as a measurement tool without genre bias (Sheehan, 2016), it is still unclear whether their tool can access the difficulty specifically for language in science.

SCI-SCI-Reading, the readability tool developed in this study also uses NLP techniques to explore language features, but it has a more specific and practical focus on the secondary science classroom. Why do science teachers need a specific readability measurement tool? When engaging in reading science, science teachers usually focus on the specific science content they want their students to know from the text, while usually unaware of the difficulty of the scientific language and academic language that may prevent their students from fully comprehending the science behinds the text (Snow, 2010; Rhodes & Feder, 2014). *WordSift*, an online literacy tool developed by Stanford University (https://wordsift.org), aimed to help teachers to better manage the vocabulary of specific reading material to support English Language Learners (ELL), but it is not appropriate enough for secondary science classrooms: (1) it's readability measurement is still dependent on the traditional formula; (2) based on a science vocabulary list (Marzano & Pickering, 2005), it can only identify a limited size of science words; (3) the identified science words are not grade-specific so that results will be thrown off by words such as "night" and "sun" because they, in general, offer very little

challenge for secondary readers. Therefore, an improved reading tool for analyzing secondary science text will be more valuable and helpful.

Methodology

This study conducted a progressive corpus-based analysis using the Python Programming Language. Both sets of training corpuses and testing corpuses were manually built by the author (Table 1). A text data cleaning process was completed with the help of Natural Language Tool Kit packages and regular expressions (Bird et al., 2009). Two vocabulary lists were built for feature selection: (1) the academic language features were based on the Academic Word List (Coxhead, 2000); (2) the scientific language features were originally developed by extracting science terms from Oxford Reference (http://www.oxfordreference.com). The word list "1000 Most Common Words in English" was used to filter out science words that had little challenge for secondary readers (n.d.). There are two reasons for choosing to build the Science Word List through a dictionary rather than through the existed vocabulary lists: (1) the programs aimed to maximize the chance to identify science words, especially for post-secondary, unfamiliar words; (2) the program aimed to include words that are "semi-technical" or "non-technical words but widely used in science" under the difficulty consideration (Wellington & Osborne, 2001, p.18). Due to the limitation of the program, the science phrases were divided into separate words when building the dictionary.

Use	Source	Grade		Number of Articles				
			Life Science	Earth Science	Physical			
					Science &			
					Technology			
Training	NEWSELA	3-4	180	140	80	233638		
		5-6	180	140	80	291904		
		7-8	180	140	80	330801		
		12	180	140	80	400142		
	Scientific	Post-		200		583738		
	American	Secondary						
		Total		1800		1840223		
Testing	NEWSELA	5-6	30	30	20	59775		
		7-8	30	30	20	78425		
		12	30	30	20	82170		
		Total		240		220370		

Table 1.			
Science Articles for Traini	ing and for Testi	ng SCI-SCI-R	eading

Note. Secondary-Level articles were collected from "Text Sets for Science" in NEWSELA (https://newsela.com/textsets/#/science). Post-Secondary articles were collected from Nature.com (https://www.nature.com), with advanced searching: "Special Features", " *Scientific American*", "Last 2 years". Token are counted after text data cleaning.

Table 2.

		Academic Words		Science Words
	Size	Examples	Size	Examples
Pre-Secondary	314	accurate, estimate, item	1773	galaxy, robot, battery
Gap between 3-4 and 5-6	126	modify, interpret, ratio	553	residue, zoology, cooper
Gap between 5-6 and 7-8	55	distort, dimension, accommodate	394	zygote, fungi, flora
Gap between 7-8 and 12	40	aggregate, invoke, successor	497	immunology, segment, acetic
Post-Secondary	N/A	clause, forthcoming, whereby	N/A	insulin, Eocene, quench

Note. "Gap between 3-4 and 5-6" include words that first appeared in Grades 5-6 articles.

Information Retrieval (IR) techniques were used for developing this computer program. Words with common roots were treated as equivalent (stemming). Instead of using a standard vector space that packs all selected words into a single collection of vectors, one novel technique in this study was to classify the "gap words" as grade-specific features (Table 2), and then to pack them into multi-layered vector spaces with grade-specific weights. For examples, the word "accurate" was weighted 4.0 because it first appeared in Grades 3-4, and "distort" was weighted 8.0 because it first appeared in Grades 7-8. Next, the vectors were weighted one more time by using TF-IDF (Term Frequency-Inverse Document Frequency), an algorithm that reflects the importance of a word to a document (Jurafsky & Martin, 2014). Cosine Similarity was used to compare the weighted vectors between one testing article and the sets of training articles classified by 3 secondary reading levels. The testing article would then be categorized into a specific reading level associated with the highest similarity score. In the readability test, SCI-SCI-Reading evaluated the difficulty of using academic words and using science words separately. Finally, the performance of SCI-SCI-Reading — how accurate it could predict the grade level of a science text — was evaluated by three standard performance measures for IR: Precision, Recall, and F-measure.

Results and Discussion

Firstly, the statistical results confirm the hypothesis that NEWSELA can become a reliable data source to measure the difficulties in science reading. As Figure 1 shows, the language use in the NEWSELA graded articles represents a trend: the demand of both academic words (AWL) and science words (SCI) is correlated with the reading level. Secondly, the similarity between the increasing rate of AWL and the increasing rate of SCI implies that when reading science, the academic language has at least the same degree of difficulty as the scientific language for secondary

students (Figure 1). The biggest gap (128 words) in using academic words is shown between Grades 3-4 and Grades 5-6 (Table 2), which reminds the middle school science teachers to pay special attention to access the difficulty of academic language when assigning the reading materials. Thirdly, as Table 4 shows, SCI-SCI-Reading is shown to be effective in differentiating both the difficulty of academic language (M = 81.7%) and the difficulty of science language (M = 83.5%) between middle school and high school. For middle school science articles only, SCI-SCI-Reading is more likely to differentiate Grades 5-6 and Grades 7-8 by using SCI (M = 69.7%) than using AWL (M = 63.3%).



Note. The academic and science word lists consist of 570 and 14,457 (stemmed) words respectively.

Figure 1. Using A	Academic Words	and Science Wo	ords in Four P	re-College	Reading Levels
-------------------	----------------	----------------	----------------	------------	-----------------------

Performance	of SCI-SCI-F	Reading for	Reading Leve	l Classificatio	n	
	Academ	nic Words Meas	surement	Scienc	e Words Measu	urement
-	Precision	Recall	F-measure	Precision	Recall	F-measure
Grades 5-6	0.637	0.725	0.678	0.611	0.825	0.702
Grades 7-8	0.536	0.46	0.495	0.635	0.588	0.610
Grade 12	0.725	0.725	0.725	0.845	0.613	0.710
Mean	0.633	0.637	0.633	0.697	0.675	0.674
	Precision	Recall	F-measure	Precision	Recall	F-measure
Grades 5-8	0.863	0.863	0.863	0.830	0.944	0.883
Grade 12	0.725	0.725	0.725	0.845	0.613	0.710

Table 3.

0.817

Mean

0.817

Using SCI-SCI-Reading a teacher can input any desired text into the program to evaluate its appropriateness for the student. Figure 2 demonstrates how science teachers can use SCI-SCI-Reading to evaluate the difficulty of the one reading material, by text, by sentence, and by word. As Figure 2 shows, science phrases such as "carbon dioxide" and "greenhouse gases" can only be detected as separate words. This limitation is possible and hopeful to be solved in the future study by applying two more NLP techniques, Phrase Extraction and Name-Entity Recognition (NER).

0.817

0.835

0.834

0.825

This computer program is still going through review and will be made available online or as an App as soon as possible.



Figure 2. Demonstration of a Text Analysis Provided by SCI-SCI-Reading

There are two major benefits of using this computer tool in secondary science classrooms: (1) saving time; (2) a close evaluation of the any desired written materials in terms of the two major challenges in science reading: academic language and scientific language. Unlike previous readability measurements providing only a score, SCI-SCI-Reading's close evaluation of each sentence helps science teachers to quickly locate which sentence or word is potentially challenging for reading comprehension. Furthermore, this tool will be especially beneficial for the classroom with students who have varied reading abilities such as ELL/ESL and Specific Reading Comprehension Deficits (S-RCD). As Swanson and Wexler suggest, the first step in providing students with disabilities with access to the content through text reading is to select high-quality texts that are well matched to student needs (2017). With a complete text analysis by SCI-SCI-Reading, more specific reading instructions could be prepared when science teachers have a better understanding the sources of students' challenges.

Implications

This study is novel and meaningful because it uses Natural Language Processing techniques to solve a specific challenge for secondary science teachers. Currently, SCI-SCI-Reading is a computer program in the author's own computer, but after gaining more feedback from science teachers and science educators, this tool will be ready to publish online or be developed as an educational App. Furthermore, the author believes that the corpus developed in this study is valuable and suitable to investigate more language features specifically for language in science.

References

- 1000 most common words in English | Learn English. (n.d.). Retrieved July 30, 2017, from http://www.ef.edu/english-resources/english-vocabulary/top-1000-words/
- Bird, S., Klein, E., & Loper, E. (2009). Natural language processing with Python:.
- Coxhead, A. (2000), A New Academic Word List. TESOL Quarterly, 34: 213-238. doi:10.2307/3587951
- Jurafsky, D., & Martin, J. H. (2014). Speech and language processing: an introduction to natural language processing, computational linguistics, and speech recognition. India: Dorling Kindersley Pvt, Ltd.
- K. Collins-Thompson, J. Callan. Predicting reading difficulty with statistical language models. *Journal of the American Society* for Information Science and Technology. Vol. 56, No. 13, 1448-1462.
- Lexile Analyzer®. (n.d.). Retrieved July 23, 2017, from https://www.lexile.com/analyzer/
- Marzano, R. & Pickering, D. (2005). *Building academic vocabulary: Teacher's Manual*. Arlington, VA: Association for Supervision and Curriculum Development.
- National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010c).
- Common Core State Standards for English language arts and literacy in history/social studies, science, and technical subjects: Appendix A. Research supporting key elements of the standards. Washington, DC:
- Newsela begins publishing Scientific American content adapted for K-12 readers. (n.d.). Retrieved July 23, 2017, from https://newsela.com/pages/release/2014-09-22-newsela-begins-publishing-scientific-americancontent/
- Newsela | Nonfiction Literacy and Current Events. (n.d.). Retrieved July 23, 2017, from https://newsela.com/
- Osborne, J., Sedlacek, W., Friend, M., & Lemmi, C. (2016). Learning to Read Science. Science Scoop 36-42.
- Rhodes, H. G., & Feder, M. A. (2014). Literacy for science: exploring the intersection of the next generation science standards and common core for ELA standards: a workshop summary. Washington, D.C.: The National Academies Press.
- Shanahan, T., & Shanahan, C. (2008). Teaching Disciplinary Literacy to Adolescents: Rethinking Content-Area Literacy. *Harvard Educational Review* 78(1), 40-59. doi:10.17763/haer.78.1.v62444321p602101
- Sheehan, K. M. (2016). A Review of Evidence Presented in Support of Three Key Claims in the Validity Argument for the TextEvaluator® Text Analysis Tool. *ETS Research Report Series,2016*(1), 1-15. doi:10.1002/ets2.12100
- Si, L., & Callan, J. (2001). A statistical model for scientific readability. Proceedings of the tenth international conference on Information and knowledge management - CIKM01. doi:10.1145/502692.502695
- Snow, C. E. (2010). Academic Language and the Challenge of Reading for Learning About Science. *Science*, 328(5977), 450-452. doi:10.1126/science.1182597
- Swanson, E., & Wexler, J. (2017). Selecting Appropriate Text for Adolescents With Disabilities. *TEACHING Exceptional Children*,49(3), 160-167. doi:10.1177/0040059916670630
- Wellington, J. J., & Osborne, J. (2001). Language and literacy in science education. Buckingham: Open University.

Acknowledgements

The author would like to thank Dr. Adam Meyers, Dr. Robert J Wallace, and Dr. Miriam E

Ebsworth for guidance and useful advice to support this study.

LOOKING BEYOND GRAPHICAL REPRESENTATIONS WITH TRANSNUMERATION

Michael Daiga Wittenberg University daigam@wittenberg.edu

This study explores preservice teacher Statistical Knowledge for Teaching with regards to their understanding of transnumeration, a type of statistical thinking involving graphical representations. Released items from AP-Statistics were used to write tasks reviewed by inservice teachers and administered in a survey to preservice teachers. Findings suggest preservice teachers content knowledge was the main avenue utilized in thinking about transnumeration. Preservice teachers struggled to answer questions about the Knowledge of Content and Students, especially when they completed tasks incorrectly.

Introduction

Statistical Knowledge for Teaching (SKT) is a focal point for statistics education research because of its impact on student learning outcomes. SKT frameworks (Burgess, 2006; Groth, 2007; Haines 2015) along with political documents like the recently published *Statistical Education of Teachers* report (American Statistical Association, 2015) established standards for improving preservice teacher's SKT. But the growth in high school statistics classes is straining the population of welltrained high school statistics teachers. The *Advanced Placement Statistics (AP-Stats)* courses alone have grown from 10,000 to over 200,000 students taking the exam over the past 20 years (Pierson, 2016). Statistics education is at a critical juxtaposition with the demand for well-trained statistics educators being extremely high, but current secondary preservice teacher coursework mainly focused on mathematics. During this critical time of growth for statistics whose importance spans across STEM fields, research can improve teacher knowledge changing how statistics is taught in K-12 education.

Objectives of the Study

The goal of this study was to investigate preservice teachers SKT using graphical representations specifically with the concept of transnumeration (Wild & Pfannkuch, 1999). Transnumeration is a type of statistical thinking where new insight into a phenomenon is produced by organizing raw data in a different representation. For example, when teachers draw a simple graph, *t*-table, or even a picture of a statistical situation on how a problem is solved, students can use transumerative thinking to find additional statistical information through that graphical representation that was not known before the graphical representation was made. In order to study

the phenomenon of transnumeration, released items from the AP-Stats exam were used as a platform to write tasks for preservice teachers to solve and discuss answers, a research technique that other researchers have pursued (Groth, 2014; Watson, Callingham, & Nathan, 2009). Each task developed helped to answer the following research questions:

- 1) What do secondary mathematics preservice teachers know about transnumeration?
- 2) What do secondary mathematics preservice teachers think that high school students know about transnumeration?

Theoretical Framework and Related Literature

Shulman (1986) highlighted the importance of understanding different types of teacher knowledge in various subject matters. In mathematics education, his work was a precursor to the construct Mathematical Knowledge for Teaching (MKT), which had a profound influence on Statistical Knowledge for Teaching (SKT). Some researchers described SKT in a broad manner (Burgess, 2006; González, 2016; Groth, 2007; Haines, 2015), while others focused on specific types of knowledge or beliefs that were involved in teaching statistics (Batanero, Godino, & Roa, 2004; Casey, 2008; Watson, Callingham & Nathan, 2009). With the complex nature of teaching, researchers used different techniques to describe the art and science of SKT.

This research project focused on the overlap of transnumeration and specific knowledge categories in the Burgess SKT framework (2006), which was based on lesson and interview recordings along with research literature ideas from teacher, mathematics, and statistics education. The framework combines Hill et al.'s (2004) classifications of SKT in a matrix with the components of statistical thinking and empirical inquiry from Wild and Pfannkuch's research (1999), including transnumeration. Although Burgess's tool provided a manner to evaluate teacher lessons, little is known about the interaction of SKT categories and transnumeration.

Methodology

This research project was a multiple method, iterative process of creating and revising tasks based on AP-Stats assessment items, administering a survey of the tasks, and conducting paired taskbased interviews from survey results. Creating and revising tasks began by repurposing AP-Stats' released items into tasks that encouraged survey-takers to answer using transnumeration. The 16 strongest tasks were sent for review to four high school statistics teachers who had an average of 23 years of experience teaching mathematics and 13.25 years of experience specifically teaching statistics along with one associate professor of statistics. Reviewer feedback was used to revise tasks and decide on a set of seven tasks to use as survey to study secondary preservice teachers knowledge. Specifically, reviewers were asked how closely tasks targeted transnumeration, what teacher knowledge categories each task focused on, and the extent to which interviewing preservice teachers about each of the tasks would provide insight into their ability to use transnumeration. After each task, the preservice teachers completed a short series of belief questions about the task's value, motivation, and what might be done to help high school students complete the task.

The survey was administered to three groups of preservice teachers in a secondary mathematics program at a large university in the midwest. Respondents were categorized into different three different exposure levels with university coursework, as the Guidelines of Assessment and Instruction in Statistics Education report suggests exposure to statistics is a better classification of knowledge than age (Franklin, 2007). The Alpha group (n=13), mostly freshmen and sophomores, was the least experienced in statistics and pedagogy. This group had not taken AP-Statistics in high school and took at-most one course in college that was either focused on statistics or teaching mathematics. A second group, called the Betas (n=11) had additional exposure to statistics and teaching mathematics. Betas either passed AP-Stats in high school (a year-long course), or they had finished at least two courses in college involving either statistics or teaching mathematics. The final group of preservice teachers, the Omegas (n=13), had the most experience in statistics and teaching mathematics. All Omegas were seniors or graduate students with a range of exposure to statistics and teaching mathematics. Omegas had taken or were enrolled in at least four courses about statistics or teaching mathematics. Because GPA can be an indicator of mathematics knowledge (Chance, Wong, & Tintle, 2016), group GPAs were compared. The GPAs for the three groups were not statistically different at the high school or college levels (Table 1) suggesting that any differences between groups in performance on the survey would be due to exposure to mathematics and statistics content more so than mathematics aptitude.

Table 1. Group GPA Results

	<u>Alphas (n=13)</u>	Betas (n=11)	Omegas (n=13)
Average college GPA	3.18	3.24	3.34
Average high school GPA	3.91	3.82	3.84

After survey completion, 32 of the preservice teachers were interviewed in pairs about what their responses to the survey. In addition to discussing their responses to the each of the seven

survey tasks, the teachers responded to questions designed to evaluate their knowledge of transnumeration through Common Knowledge of the Content (CKC) and Knowledge of Content and Students (KCS). Constant comparison tables were used to identify program developmental stages and beliefs of preservice teachers in the teacher education program.

Results and Discussion

Survey results across the seven tasks are presented below in Table 2. Two scores are presented for each group: *fully correct results* and *partially or fully correct results*. For this research study three of the seven tasks had multiple correct answers so respondents who provided one but not all the correct answers were scored as partially correct. Distinguishing between fully correct and partially correct answers provided some additional insight on what kind of knowledge preservice teachers really had about graphical representations and transnumeration.

Table 2.Comparison of the Average number of Correct Answers for Seven Tasks

	Fully Correct	Partially or Fully Correct
Alphas (n=13)	2.23	3.77
Betas (n=11)	2.18	4.36
Omegas (n=13)	2.54	5.00

Fully correct responses across Alpha, Beta, and Omega groups were relatively consistent (2.23, 2.18, 2.54) and showed that most of the preservice teachers struggled with the tasks. No statistically significant differences between groups were found through ANOVA (F (2,34) = 0.227, p = 0.798). Perhaps one reason for low scores was that tasks combined statistical content and pedagogical knowledge, which are both unique and difficult knowledge types to cultivate for students. (Haines, 2015; Watson, Callingham & Nathan, 2009). The average scores for partially correct increased across all groups with Alphas (3.77), Betas (4.36) and Omegas (5.00), although there was no statistically significant differences between group means as determined by one-way ANOVA (F (2,34) = 1.509, p = 0.236).

Belief Results

After each task, preservice teachers were asked five belief questions about each task on a seven point Likert scale (1-strongly disagree, 2-disagree, 3-somewhat disagree, 4-neutral, 5-somewhat

agree, 6-agree, 7-strongly agree). Table 3 shows the average responses from each group with regards to their beliefs about each task.

Table 3.Belief Results of the Seven Tasks by Group

	<u>Alphas</u>	<u>Betas</u>	<u>Omegas</u>
1) This question is about a topic I have studied in a college class.	2.64	4.35	4.70
2) I am good at answering questions like this one.	3.62	4.43	4.49
3) I often feel nervous when I try to answer questions like this one.*	4.16	4.27	4.22
4) If I try hard, I can usually figure out questions like this one.	4.32	4.78	5.24
5) Secondary mathematics teachers should know how to answer this question.	5.60	5.35	6.22

Note: The third belief question was worded so the higher the score, the more a preservice teacher felt nervous. Presumably, we would like preservice teachers to have a low score on this item.

Belief responses were substantially different between groups for some of the questions. Alphas consistently stated they studied material less in college classes, responding with an average ranking of 2.64 compared to Beta (4.35) and Omega (4.70) respondents. These differences were statistically significant between group means as determined by one-way ANOVA (F(2,34) = 97.813, p < 0.001). Given that there were seven juniors, two sophomores, and four freshmen in the Alpha group, coursework taken should have included some of the statistics needed to complete the tasks. With the increase in averages for items 1), 2), and 4) over the course of the program, there is evidence that preservice teachers believed they were becoming better teachers.

Interview Findings

Interview findings were perhaps even more robust than survey results across groups on the limited ability respondents had to complete transnumeration tasks successfully. After survey results were compiled, tasks were coded and analyzed for interview responses to questions exploring transnumerative thinking and knowledge categories. To solve the Tips Task, preservice teachers had to relate how changes to a dataset would affect a histogram and an arithmetic mean and median. Twelve of the 16 respondents who showed evidence of using transnumerative thinking on the Tips Task responded completely correct (75%) whereas respondents coded without transnumerative thinking answered correctly only 11% of the time. This finding suggests visualizing "hidden" aspects in the dataset was a critical advancement to answering the Tips Task correctly. One of the interview

questions asked respondents if a high school student would see anything different from the graphical representation than they see. Twenty-two of the 32 interviewees (69%) considered their own knowledge of the statistics used to solve the Tips Task to be the same as the knowledge of a high school student. Nineteen of these individuals (86%) justified their beliefs by talking about how the graph in the Tips Task was basic to interpret. Although respondents were learning how to teach secondary mathematics, the majority failed to highlight any potential misunderstandings within the content of the Tips Task that secondary students would confront them with.

Another task, nicknamed the Fuel Task, required respondents to transnumerate information between a histogram, and boxplot and a table containing the five number summary of the distribution. The Fuel Task actually had two correct answer choices of which only one Omega and one Beta respondent answered both correctly. Eight out of 13 (62%), eight out of 11 Betas (73%) and ten out of 13 (77%) Omegas answered the Fuel task fully or partially correct. Overall, interview findings suggest that respondents who stated that there was not a difference between secondary students knowledge and their own knowledge struggled on the Fuel Task, with two out of six (33%) getting the task partially correct and the rest being completely incorrect. This suggests a respondent who could not think about differences between high school students and themselves as future teachers typically did not have strong content knowledge. Respondents who made statements that were coded for explicit differences between their knowledge and high school students knowledge did better than those who did not explicitly state differences, with 15 of the 19 (79%) answering at least partially correct. Only three preservice teachers made multiple statements that were coded about differences between students and themselves, with two of those respondents being the Beta and Omega respondents who answered the Fuel Task completely correct.

Implications

Transnumeration is a difficult type of thinking to utilize when interpreting and solving a statistical problem. However, being able to transnumerate within a graphical representation was a critical skill that made a difference in the success of completing the statistical tasks used in this survey. Because survey evidence showed that many preservice teachers did not have the necessary CKC to solve tasks correctly, additional tasks should be created that require transnumeration to complete, but are more familiar topics for respondents. Instructional time needs to be spent in methods courses explicitly discussing the differences between CKC and KCS, providing preservice teachers opportunities to discuss both content and the statistical content knowledge of secondary

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

students. Discussions should span across different statistical subjects (e.g. medians, hypothesis testing) because preservice teachers struggled to articulate their statistical knowledge.

References

- Franklin, C., Bargagliotti, A., Case, C., Kader, G., Scheaffer, R., & Spangler, D. (2015). Statistical education of teachers. Alexandria, VA: American Statistical Association. Retrieved from http://www.amstat.org/education/SET/SET.pdf.
- Batanero, C., Godino, J., & Roa, R. (2004). Training Teachers To Teach Probability. *Journal of Statistics Education 12(1)*, 1-19.
- Burgess, T. A. (2006). A framework for examining teacher knowledge as used in action while teaching statistics. In Rossman A. & Chance C. (Eds.), *Proceedings of the Seventh International Conference on Teaching Statistics, Salvador, Bahia, Brazil*, Retrieved from https://iase-web.org/Conference_Proceedings.php
- Casey, S. A. (2010). Subject matter knowledge for teaching statistical association. *Statistics Education Research Journal, 9(2),* 50-68.
- Chance, B., Wong, J., & Tintle, N. (2016), Student Performance in Curricula Centered on Simulation-Based Inference: A Preliminary Report. *Journal of Statistics Education*, 24(3),114-126. <u>https://doi.org/10.1080/10691898.2016.1223529</u>.
- Franklin, C., Kader, G., Mewborn, D., Moreno, J., Peck, R., Perry, M., & Scheaffer, R. (2007). Guidelines for assessment and instruction in statistics education (GAISE) report. Alexandria VA: American Statistical Association. Retrieved from <u>http://www.amstat.org/education/gaise/</u>.
- González, O. (2016). A framework for assessing statistical knowledge for teaching based on the identification of conceptions of variability held by teachers. In D. Ben-Zvi & K. Makar (Eds.) *The Teaching and Learning of Statistics* (pp. 315-325). Springer International Publishing.
- Groth, R. E. (2007). Toward a conceptualization of statistical knowledge for teaching. *Journal of Research in Mathematics Education, 38*, 427-437.
- Groth, R. E. (2014). Using Work Samples from the National Assessment of Educational Progress to Design Tasks that Assess Statistical Knowledge for Teaching. *Journal of Statistics Education*, 22(3), 1-28.
- Haines, B. (2015). Conceptualizing a Framework for Advanced Placement Statistics Teaching Knowledge. Journal of Statistics Education, 23(3), 1-16.
- Lee, H., Kersaint, G., Harper, S., Driskell, S., Jones, D., Leatham, K., Agnotti, R., Adu-Gyamfi, K., (2014). Teachers' use of Transnumeration in solving Statistical Tasks with Dynamic Statistical Software. *Statistics Education Research Journal*, 13(1), 25-52.
- Pierson, S. (2016). AP Statistics Sustains Strong Growth in 2013 [Chart updated through 2016]. American Statistical Association. Retrieved from <u>http://community.amstat.org/blogs/steve-pierson/2013/10/04/ap-statistics-sustains-strong-growth-in-2013</u>.
- Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14.
- Watson, J. M., Callingham, R., & Nathan, E. (2009). Probing teachers' pedagogical content knowledge in statistics: How will Tom get to school tomorrow? In R. Hunter, B. Bicknell, & T. Burgess (Eds.), Proceedings of the 32nd Annual Conference of the Mathematics Education Research Group of Australasia (pp. 563-570). Palmerston North, New Zealand.
- Wild, C. J., & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry. International Statistical Review, 67(3), 223-248.

SUPPORTING STEAM PRACTICES WITH DIGITAL NOTEBOOKING

Bridget Miller Christie Martin University of South Carolina, Columbia

Scientific notebooks are a well-established practice in science education and are considered an essential tool for supporting science and engineering practices (Miller, Krockover & Doughty, 2013; Cambell & Fulton, 2003). Incorporating digital technologies for notebooking offers students' opportunities to engage with several mediums to scaffold their learning, and enables educators to address limitations and challenges of diverse learners. In this study, we explore the use of electronic notebooking practices (e-STEAM) to provide multiple mediums through interactive technology. We found digital notebooks afforded students the opportunity to further their scientific literacy and fosters their own writing of non-fiction informative texts.

Introduction

Science notebooking has been a part of the science classroom for many years and are an essential tool for supporting science and engineering practice (Miller, Krockover & Doughty, 2013; Cambell & Fulton, 2003), traditional notebooking creates a space for students to write, make scientific illustrations, and collect relevant inserts. However, the use of traditional notebooking methods have demonstrated barriers in reaching science inquiry objectives for populations of students who lack fluent written literacies, such as students with disabilities and young students who have yet to master written communication (PreK-2) (Miller et al., 2013). With today's students being digital natives, comfortable with navigating and operating today's technologies, the benefits of tablet e-notebooks (Presnkey, 2006) have potential for providing modes of communication and assessment for students in the classroom (Miller et al., 2013).

Objectives of the Study

The study intended to examine the impact of digital notebooking on second grade students engaging in a science lesson. The students were unfamiliar with using this technology, which made the study exploratory. The purpose of examining the impact was to see how students used the technology, their engagement, what they produced, and what this data indicated for future lessons.

Related Literature and Theoretical Framework

Writing has been found to facilitate student's critical thinking and learning across a variety of content areas (Vacca, Vacca & Mraz, 2011). STEM and literacy educators support notebooking as a tool to encourage writing across the curriculum and provide opportunity to critically think (Vacca,

Vacca & Mraz, 2011), and also note that linking literacy and science standards can serve as a formative assessment tool (Klentschy, 2010; Eidger, 2012). Incorporating digital technologies for notebooking offers educators the opportunity to address limitations and challenges of diverse learners and allows students to engage with several mediums to scaffold their learning experience. Notebooks in science education have become an essential tool for supporting student's scientific inquiry in and across concepts (Miller, Krockover & Doughty, 2013; Cambell & Fulton, 2003). Scientific notebooks not only support students scientific and engineering practices but they play a large role in connecting science to both todays' literacy standards, and formative assessment strategies of student's learning (Klentschy, 2010; Eidger, 2012). Notebooks; are a place to record questions, document observations, plan experiments, evidence, note explanations and are used by students and professionals. Digital notebooking is a valuable tool for reflection, revision, recording, communicating, and assessing students' inquiry and engineering design processes (Miller et al., 2013; Klentchey 2010).

Traditional notebook practices are commonly used in the science classroom; however, they may present challenges for young students who have not mastered written communication skills. Early childhood students (Pre-K-2), as well as students with multiple disabilities ranging from learning disabilities (LD), cognitive disabilities (CD) and other health impairments (OHI) may require additional supports to master and fully engage in note booking, this is not to say it shouldn't be used (Miller et al., 2013; Miller & Krockover, In press; Miller & Doughty 2014). Educators are seeking innovative ways to provide and incorporate a variety of mediums to engage all students (Figure 1).

e-STEAM Note Books	Traditional Note Books
Writing Typing Scientific Illustration Images (Image Capture) Dictation Recording(video) Data Collection (probewear /Ap	Scientific Illustrations Writing Artifacts Inserts/Handouts

Figure 1. Modes of Communication for traditional note books and e-STEAM Note books

Today's generation of students are considered "digital natives." Their regular daily engagement with technology suggests this would be a place to advance traditional notebooking. This familiarity makes the benefits of *electronic-notebooks* a valuable tool for providing a variety of modes of communication, assessment, and differentiation for diverse students in the classroom (Presnkey, 2006; Miller et al., 2013). Providing electronic forms of scientific notebooks or (e-STEAM notebooks) to students offers the opportunity to continue with the activities such as writing and drawing that are available through traditional notebooking and also have access to additional outlets of communication that may be more appropriate. These added outlets may enhance expression that static paper pencil doesn't afford. For example, on an "w-STEAM" notebook, students can conduct recording dictations, take images, recording video logs, recording voice captions with drawings, or typing when collecting and analyzing data (Miller et al., 2013). If a student is not proficient in written communication there is an undue burden that writing in traditional notebooks can create and this takes away from a student's ability to focus on the scientific or engineering process, and in turn, impact the quality of work (Miller 2012; Miller et al., 2013: Pass, 2010; Kalyuga, Renkl & Pass, 2010).

The theory behind e-STEM notebook scaffolds is to lessen students cognitive load to increase focus on the current objective. The cognitive load is reduced by providing multiple avenues for collecting, reporting, and communicating their ideas.

Methodology

The researchers conducted the study in one second grade classroom. The teacher was consulted with prior to the lesson to determine the science lesson and the students experience with technology in the classroom. The researchers were informed that the students had not previously worked with this medium and that a review of states of matter was the preferred topic to plan a science inquiry. The researchers planned for an inquiry into the states of matter with hands on activities and prepared an introduction at the beginning for using the iPad and specifically Educreations© Application.

The lesson began with discussion to activate prior knowledge related to liquids, solids, and gases. Each student was given half of a Popsicle, clear cup, and straw. Students squeezed the frozen Popsicle into the cup and began to discuss how it might change, why those changes would occur, what could be done to accelerate the process, how could you decelerate the process, and what states of matter would be observed. They used their iPad to record their thinking and observations through pictures, drawings, writing, and recording. Researchers circled around to the different tables to assist with technology and ask probing questions. In addition to the individual Popsicle experiment the researchers gave a demonstration of placing a Popsicle on a hot plate. Students shared predictions prior and discussed what was happening during. The 5E lesson plan for this activity is captured in Figure 2.

Multiple Media in E- Notebooks: Following the 5-E Learning Cycle: 1. Engage	Common Core: CCSS.ELA- LITERACY.CCRA.W.6 Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others. Essential Question: I brought some ice pops to share with you but, oh no something happened to some of them (they are in liquid state)! What is going on? When I left they weren't like this! We can't eat popsicle soup can we? Ice Pops; Changing States of Matter: With an empty container (one left open on a porch in the sun for days), a liquid one and a frozen one, students make observations and inferences about each. (Use guiding questions until you get them to states of matter, "I heard someone say it was solid and now liquid, it changed states. What do you mean by that?")	CCSS.ELA-LITERACY.CCRA.W.2 Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content. Notebook Entry : KWHL, What do you know about states of matter? (Pre-assessment, What do they know from prior).
2. Explore	Students are given a frozen pop and asked, "Can you find a way to change its current state?"	 Notebook Entry: How could you change the pop from one state to another? Design a plan. Students can draw, write, type, and/or dictate an initial design. (1) Observe: Document what you observe, tell me everything about the pop you currently have (color, smell, taste, temperature, weight) (2) Plan: Design and explain how you will change its current state. What materials do you need? How will it work? What data will you collect? (3) Collect: Collect and record your data. What state did you start at? What state did you end at? What data did you collect? What dependent and independent variables did you measure? How did you measure them?
3. Explain	Modeling: Popsicle Cycle (States of Matter) Whole Group: Students Share Different ideas: Share notebooks on larger screen; Look across data, compare methods and ideas. Discuss results; Gain whole group feedback. "Why do you think mashing with a straw worked faster than holding in their hands?" Teacher facilitates lesson on content related to students to ideas about particles (depending on student level), heating and cooling, application of heat	Notebook Entry: What happened and why? How could you illustrate what is occurring? (Students generate models) 4) Analyze: How did your model (or revised model) work?
4. Elaborate	Quickest way to melt (Lamps, Sun, Hands, Breath) Conductors and Insulators: Engineering Design: Creating Containers (Coolers)	Notebook Entry : What would be the fastest way to make popsicle soup? Why?
5. Evaluate	Formative Assessment: Scientific Models and Electronic Notebooking. Teachers can look at student's notebooks either physically handed in or submitted via dropbox and identify misconceptions.	

Figure 2. The 5 E Lesson plan

Data collection included the students work in the e-STEM notebook on their iPad which was downloaded, classroom observations, and discussion with the teacher. The data from the notebook was transcribed and analyzed to examine the impact of using this technology for student learning.

Results and Discussion

The analysis of the student's work on Educreations indicated that students engaged with the multimedia options offered through stem-notebooking by expressing their thinking through multiple mediums. Figure 3 shows how two students used the technology to capture their ideas.



Figure 3. E-Stem Notebooking.

Student D used the camera option to take before and after photos of the popsicles in the cup. In the after photos the student wrote notes "blow on it," "heat it," "break it with your straw," "take it outside," "now they are melted" and drew an arrow to show what was happening in the picture. The student used the recorder option to dictate what was happening in the picture. Student E was at the same table and added another picture next to the note "take it outside" and typed "now it is gas" which indicates the student recognizes the sun would provide the level of heat necessary to cause another change in the state of matter. Student E also used the record option to discuss their though process and explain their work. These examples were consistent with the other students work and

indicate the students felt comfortable using the technology. These entries remain and can then be referred to for the next lesson.

Implications

In an age where students are digitally inclined, the use of digital mediums to extend traditional scientific notebooking practices may hold promise. As many digital notebook and whiteboard applications now allow for multiple ways to record information, it naturally allows students to differentiate how they produce artifacts to communicate their understanding of scientific concepts. The Next Generation Science Standards (NGSS, 2013) emphasize the use of scientific modeling that can predict and communicate information. This form of digital notebooking is a valuable tool for students in the creation of scientific models as demonstrated in this pilot class. Students used a variety of ways to generate models for states of matter, for example using drawing and audio narration, using images and text, using text and drawing, and using images and narration. Regardless of the method for communicating the concepts all students were able to communicate in their method of choice their understanding. An additional benefit to accessing digital note book methods is the ability to share virtually. Not only can students communicate information on their own devices, but now they can share their work with teachers, peers, and family at home. Students can save and access old notebooks, modify notebook entries based on new knowledge, and share their findings beyond a single viewer. Today's applications are now generating class settings to easily observe and share within a closed group and accessed across hardware (tablet, laptop, smart phone). Lastly a benefit that extends beyond traditional notebooks is that digital devices can also let students access additional resources and information when conducting an investigation. Whether it be the local weather, GPS, reference material, or using data collection tools like probeware, students can access the information on the same device as their notebook and directly when needed.

Although there are several benefits to digital notebooking methods, not all school communities have access to one-to-one technology. Although the number of schools with access to tablets and laptops continues to increase, it is not feasible for all schools and their students to date. Additional considerations for sharing utilizing digital notebooks would be access to internet or wifi for sharing, ensuring the device is charged and ready when needed, and that students are familiar with how to handle devices. Other considerations are school firewalls and servers where some districts require approval of application use.

Technology continues to be ever present in students' lives, now making its way into the classroom. Ongoing research is needed to investigate the benefits of students' digital notebooking and implementation in authentic ways, compared with traditional low tech methods used prior.

References

BeeVisual LLC. (2013). ChoiceWorks. itunes.com. Southborough, MA.

Calkins, L. (1983). Lessons from a child: On the teaching and learning of writing. Portsmouth, NH: Heinemann.

Campbell, B. & Fulton L. (2003). Science notebooks: Writing about inquiry. Canada Pearson Education.

Educreations Inc. (2014). Teach what you know: Learn what you don't.www.educreations.com Retrieved on 07/07/14.

Eidger, M. (2012). Writing in the science curriculum. Education. 133(1), 35-38.

Graves, D. H. (1983). Writing: Teachers and children at work. Portsmouth, NH: Heineman.

- Kalyuga, S., Renkl, A., & Paas, F. (2010). Facilitating flexible problem solving: A cognitive load perspective. Educational Psychology Review, 22, 175-186.
- Klentschy, M. (2010). Making meaning with notebooks. Science and Children, 43(3), 24-27.

Lead States, (2013). Next Generation Science Standards. Washington DC. National Academy Press.

- Miller, B. (2012). Ensuring meaningful access to science curriculum for students with significant cognitive disabilities, *Teaching Exceptional Children*, 44(6), 16-25.
- Miller, B., Krockover, G. H., & Doughty, T., (2013). Using iPads to teach inquiry science to students with intellectual disabilities: A pilot study. *Journal of Research in Science Teaching*, 50, 887-911.
- Miller, B., & Doughty, T. (2014). Self-monitoring checklists for inquiry problem solving: Functional problem solving methods for students with intellectual disabilities. *Education and Training in Autism and Developmental Disability* 49(4) 555-567.
- Miller, B., & Krockover, G.H., (In Press). Utilizing Visual Data with Tablet Technology in the Primary (K-3) Classroom. In K.D. Finson & J.E. Pedersen (Eds). *Application of Visual Data in K-16 Science Classrooms*. Charlotte, NC: Information Age Publishing Inc
- Murray, D. (2004). A writer teaches writing / Donald M. Murray. Boston : Thomson/Heinle, c2004.
- Nearpod (2014). Nearpod Silver. retrieved October 25, 2014. http://www.nearpod.com/
- Paas, F. (2010). Cognitive load theory: New conceptualizations, specifications, and integrated research perspectives. *Educational Psychology Review, 22*(2) 115-121.
- Prensky, M. (2006). Don't Bother Me, Mom, I'm Learning!: How Computer and Video Games are Preparing Your Kids for 21st Century Success and how You Can Help!. New York: Paragon House.
- Vacca, R. T., Vacca, J. A. L., & Mraz, M. E. (2011). Content area reading: Literacy and learning across the curriculum. Boston: Pearson.

PERSPECTIVES CHANGE ON STEM INTEGRATON: OR DO THEY?

Melanie Fields Texas A&M University-Commerce Melanie.Fields@tamuc.edu

Becky Sinclair Texas A&M University-Commerce Becky.Sinclair@tamuc.edu Christina Regian Texas A&M University-Commerce Christina. Regian@tamuc.edu

Gilbert Naizer Texas A&M University-Commerce Gilbert.Naizer@tamuc.edu

This paper highlights findings from a study that examined the effects of professional development on a group of in-service elementary math and science teachers. A unique element of the group in this yearlong program is the range in teaching tenure. The teachers have from three years to thirty-two years of teaching experience. This paper addresses how professional development changes the teachers' perspectives on STEM integration practices and concerns participants have about integrating STEM practices. Qualitative data was collected through interviews, reflections, class assignments, and classroom observations. Quantitative data was collected from the Survey of Concerns Questionnaire.

Introduction

Regardless of the number of years a teacher has taught, many still have a desire to learn. Learning may come in many forms: changes in perspective, trying new lessons, affirmation of current ideals. All of these areas of learning can be incorporated into a statement referred to as a philosophy statement. Many professional teaching arenas consider a strong philosophy one that includes a person's concept of the learning process and the role of the teacher in this process, a description of how the teacher will fill this role and, as a result, providing a justification for a person's teaching style (Chism, 1998). The world of STEM education and teacher preparation is no different. Before teachers can incorporate integrated material into a classroom, they must have a strong conceptualization of the material being taught, understand the role of both the learner and the teacher, and have a confident justification of the teaching style incorporated in the classroom. Teachers need professional learning environments in which to discuss and transform ideas (Putnam & Borko, 2000; Little, 1993).

The purpose of this study was to investigate the in-service teachers' perspectives on implementing integrated STEM lessons into their elementary science and mathematics classrooms after participating in the first year of a two-year professional development project. The project was designed to encourage the participants to continue their education, pursue a masters degree, and provide current research on instructional practices in their prospective fields. One of the primary

goals of this particular professional development program is to provide teachers additional approaches to teaching for their toolbox. The new training may facilitate changes in perspectives and concerns about implementation of strategies learned during the program.

Literature and Theoretical Framework

Previous research in the area of STEM education has focused on pre-service, middle school, and high school teachers. Very little research has been done with elementary school teachers. A longitudinal study presented evidence to support integrated STEM education by reporting a strong connection between applied math and science courses and continuing enrollment in advanced math and science courses at the high school level (Gottfried, 2015). Working with pre-service teachers, a study found 155 of 159 participants considered STEM education from an instructional and teacher centered viewpoint (Radloff & Guzey, 2016). These results were in direct opposition to the training of student-centered instruction the pre-service teachers were receiving. A separate set of researchers voiced the need for restructuring of preparation programs to include "(1) a reorganization of the knowledge bases to assist teachers in easily extracting concepts that align to authentic problems and (2) models of authentic problems that efficiently draw on the integration of the STEM disciplines within grade and relevant content knowledge and skills" (Ruggirello & Balcerzak, 2013).

A primary goal of education should be for the learner to transfer what they have learned. The learner should be able to apply previously learned information in new and unique situations (Haskell, 2001). Within this setting of educating teachers, the ideology is no different. The theoretical framework used for the development of the professional development, the observations of the teachers, and the analysis of the data come from *Transfer of Learning: Cognition, Instruction, and Reasoning.* Haskell provides a structure in which transfer of learning can be analyzed and examined by researchers and teachers alike. Although the levels of transfer are not hierarchical or mutually exclusive, each level can be illustrated through examples. Additionally, the levels of transfer are further expanded into specific types, which are defined by the kinds of knowledge used for transfer of learning. Thus, this theory provides a multi-dimensional framework to apply to the study of transfer. Each dimension can be observed in order to recognize and analyze how best to negotiate teaching for transfer.

Objective

The purpose of this research is to add to the body of knowledge of teacher preparation of elementary level teachers in the STEM fields by incorporating the concept of transfer of learning with the modeling of integration teaching strategies for math and science. Research questions for the study were: 1. What are the concerns of in-service teachers about their professional development and use of STEM Integration? 2. What is the relationship of their personal teaching philosophies and STEM integration practices?

Methodology

Currently, 10 teachers from four rural school districts located within adjacent counties in a southern state have participated in the first year of the teacher quality grant and will continue through the second year of the program. County A reports a student population of 13,219 and County *B* reports a student population of 1,872 for a total of 15,091 total students.

The emphasis for the professional development to date has been on increasing the knowledge base of the participants and empowering them with the confidence to integrate new instructional practices into elementary science and math classes. From the inception of the program, participants have been enrolled in graduate level education courses. In keeping with the goal of expanding the knowledge base, participants have taken two week-long field trips for real-world integrated math and science. In addition, there have been in class and out of class projects dedicated to integrated STEM instructional practices. Teacher participants were provided with iPad minis and many opportunities for learning and implementing the technology. Classroom instruction and participation has involved both participant led and instructor led hands-on activities with a special emphasis on recognizing math and science integration techniques. The participants are frequently asked to reflect and identify ways they can incorporate what they learn into their classrooms.

Data for the project was taken from initial interviews, personal reflections, personal teaching philosophies, and classroom observations made by two researchers. In addition to this qualitative data, participants completed the online Survey of Concerns Questionnaire (SOCQ). The participants completed the survey every six months through the professional development year and the SOCQ program analyzed the responses and generated standardized quantitative data.

Data Analyses

Interviews and reflections: Discourse analysis was conducted on the initial interviews and the personal reflections for trends of interests, which suggest changes in perspectives and concerns of the participants.

Written teaching philosophies: Teaching philosophies were analyzed and applied to a rubric created from the five guidelines for developing a teaching philosophy statement by Nancy Chism, former Director of Faculty & TA Development at The Ohio State University (Chism, 1998).

Classroom observations: Two researchers completed observations of the participants' classrooms on four separate occasions. These observations were reviewed and linked to the analysis of each teaching philosophy statement.

Survey of Concerns: Results of the online survey were analyzed for the change in concerns through the school year.

Triangulation of the three forms of data (written, observation, and survey) allowed the researchers to determine any changes in perspectives and concerns in the first year of the program.

Results and Discussion

Research Question 1: What are the concerns of in-service teachers about their professional development and use of STEM Integration?

The Survey of Concerns, developed in conjunction with the book, *Implementing Change: Patterns, Principles, and Potholes* (Hall & Hord, 2011), was analyzed for the change in concerns over the course of the first year of the professional development program. Table 1 is a brief explanation of the stages of concerns from the corresponding text. Figure 1 shows the concerns of the participants from the most recent administration of the survey. The purpose for the analysis of the most recent was to inform the researchers in the second year. For the interest of the researchers, the participants have been grouped by years of experience.

Table 1

Stage	Explanation
Unconcerned	Little concern about or involvement with the innovation is indicated. Concern about other thing(s) is more intense.
Informational	A general aware ness of the innovation and interest in learning more detail about it is indicated.
Personal	Individual is uncertain about the demands of the innovation. This includes his/her role in decision making.
Management	Attention is focused on the process and tasks of using the innovation and the best use of the resources.
Consequence	Attention focuses on impact of the innovation on clients/students.
Collaboration	The focus is on coordination and cooperation with others regarding use of the innovation.
Refocusing	The focus is on the exploration of more universal benefits from the innovations.
	Individual has definite ideas about alternatives to the innovation.
/TT 11 0 TT 1 0/	

(Hall & Hord, 2011)

The goal of all professional development programs should be a graph with a low level of intensity for the first 3 stages, *unconcerned, informational, personal*, with an increasing level of intensity for the next 3 stages of concerns, *management, consequence, collaboration,* and ending with a mid-level of intensity for the last stage of concern *refocusing* (Hall & Hord, 2011). As Figure 1 shows, our participants were not following the ideal development. However, Hall and Hord (2011) explains this is typical in the first year of change. Table 2 provides clarification of the percentages on the graph.

Yrs experience	Unconcerned	Informational	Personal	Management	Consequence	Collaboration	Refocusing
3-4	69%	51%	45%	39%	11%	36%	38%
5-10	81%	93%	89%	60%	54%	64%	42%
11-20	55%	69%	67%	49%	24%	64%	60%
21-30	81%	40%	39%	52%	11%	16%	30%

Table 2 Percentages of Stages of Concern by years of experience

Research Question 2: What is the relationship of their personal teaching philosophies and STEM integration practices?

Each participant wrote a teaching philosophy statement based on the following three questions, why do you teach, how do you teach, and why do you teach the way you do. Table 3 lists the five components of a teaching philosophy (Chism, 1998). For brevity, the actual statements from the participants have been removed and the X indicates the participant included at least one sentence regarding that component. The final column of the table includes the observation statement from the researcher after performing in class observations of the teachers and reading the individual philosophy statements.



Figure 1: Stages of Concern

For many of the participants, the assignment of writing their teaching philosophy induced stress and anxiety. During a class meeting, the discussion amongst the participants was the origin of this stress. The participant with the most experience teaching expressed that the stress was not necessarily about writing the philosophy but from revisiting and recognizing the difference in daily teaching practices. Many agreed with this analysis.

As shown in Table 3, no single participant included all five components of the teaching philosophy with *goals for students* being omitted by 60% of the participants. This seems to connect with the data in Figure 1 that shows the lowest intensity in the stage of *consequence*, which is the concern about impact on students in the classrooms.

Years of exper- ience	Concept- ualization of Learning	Concept- ualization of Teaching	Goals for Students	Implementa- tion of the Philosophy	Professional Growth Plan	Classroom Observation
32	Х	Х		Х	Х	This teacher has a wealth of knowledge on both content and classroom management. The relationship building skills developed over the years are the foundation of her classroom.
18	Х	Х		Х		This teacher has achieved the goal of relationships with her students. There is frustration when the students do not show their natural curiosity and adapting to the need to draw out this curiosity is difficult for this teacher.
17	Х	Х	Х	Х		This teacher has taught multiple age groups including adults within limited time frames. This is very evident in the classroom where there is a strong structure and student centered lessons.
16	Х	Х	Х	Х		This is a dedicated, excited, open to challenges teacher. During observations, she had a well thought out lesson that dealt with successful learning and successful citizenship.
14		Х		Х	Х	A very passionate and organized teacher, the students responded positively and the love of the profession was treated with great respect by the students.
13		Х	Х	Х	Х	been successful in every setting. The goal of being a lifelong learner and flexible in teaching is very apparent in the classroom. All lessons were student learner centered.
11		Х			Х	the classroom does contain substance. It is evident that the self-perceptions and self-worth of the students are strong factors for this teacher.
5	Х		Х	Х	Х	this is a second career. The goals for the class and the classroom setting are lofty and admirable but the execution has not been realized.
4		Х		Х	Х	This teacher sets very high standards for classroom behavior and personal interaction and models the desired behavior daily. The classroom is very organized and the students are highly engaged.
3	Х	Х		Х		This teacher struggles in the classroom with reaching the goals of her philosophy. Only in the classroom for 3 years, this teacher still struggles with the balance of classroom management and interactive learning.

Table 3Analysis of the Teaching Philosophy Statements

Previous research has shown the perception of STEM integration as teacher-centered (Radloff & Guzey, 2016). That research is mirrored by the quantitative data from the Survey of Concerns and the qualitative data of conversations and the philosophy statements. There appears to be disconnect between a general desire for a student-centered classroom and the practice of a teacher-centered classroom.

Implications

Although the study of Implementing Change allows for the development of a graph with less

concern for clients than self, the low levels of concern in consequence is cause for attention and use of

this mid-program data to inform the future development of the program. The analysis of the data

suggest the teachers require thorough experiences in STEM integration to build confidence for

integration of STEM content with the ultimate goal of transferring the strategies of the program

classroom to the elementary classroom. To truly ensure transfer, higher levels of overt and

intentional conversations plus action will likely occur.

References

Chism, N. V. N. (1998). Developing a philosophy of teaching statement. *Essays on Teaching Excellence*, 9(3), 1-2. Professional and Organizational Development Network in Higher Education.

- Gottfried, M. A. (2015). The Influence of Applied STEM Coursetaking on Advanced Mathematics and Science Coursetaking. *Journal of Educational Research, 108*(5), 382. doi:10.1080/00220671.2014.899959
- Hall, G. E., & Hord, S. M. (2011). *Implementing Change: Patterns, Principles, and Potholes* (3rd ed.). Upper Saddle River, New Jersey: Pearson Education, Inc.

Haskell, R. E. (2001). Transfer of Learning: Cognition, Instruction, and Reasoning. San Deigo: Academic Press.

Little, J. W. (1993). Teachers' professional development in a climate of educational reform. *Educational evaluation and policy analysis*, *15*(2), 129-151.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning?. *Educational researcher*, 29(1), 4-15.

Radloff, J., & Guzey, S. (2016). Investigating Preservice STEM Teacher Conceptions of STEM Education. Journal of Science Education and Technology, 25(5), 759-774.

Ruggirello, R. r. w. e., & Balcerzak, P. (2013). Enacting STEM in Teacher Development: Toward a Coherent Model of Teacher Preparation. *Teacher Education & Practice, 26*(4), 688-705.

Acknowledgements

This research was partially funded by Federal Grant # S367B140038-14B and S367B150038-

15B, awarded through the Texas Higher Education Coordinating Board.

DEVELOPING PRESERVICE TEACHERS' UNDERSTANDING OF EFFECTIVE MATHEMATICAL TEACHING PRACTICES USING VIGNETTES

Keith Kerschen	Ryann Shelton	Trena L. Wilkerson
Baylor University	Baylor University	Baylor University
Keith Kerschen@baylor.edu	Ryann Shelton@baylor.edu	Trena Wilkerson@baylor.edu

It is critical for mathematics teacher educators to emphasize connections between research and practice for preservice teachers (PSTs) in methods courses. The Mathematical Teaching Practices (MTPs) identified by the National Council of Teachers of Mathematics and Mathematical Practices (MPs) identified by the Common Core State Standards are research-based practices critical for effective mathematics teaching. This study was designed to examine secondary mathematics PSTs' understanding of the MTPs and MPs using vignettes as a reflective activity. The results indicate vignettes can be effective in helping PSTs identify and connect to the MTPs and MPs relating to their practice.

Introduction

Teacher educators are faced with the challenge of supporting preservice teachers (PSTs) as they learn to link content, effective teaching practices, and student learning through effective and meaningful experiences in increasingly diverse school settings. The Association of Mathematics Teacher Educators (AMTE) recently released the *Standards for Preparing Teachers of Mathematics*, which is a guide for the preparation of Pre-Kindergarten through 12th Grade mathematics teachers. These standards call for mathematics teacher preparation programs to emphasize and connect research and practice in mathematics instruction (AMTE, 2017). However, the connection between research and practice may be lost in translation if PSTs are not actively reflecting on research findings related to what is known about teaching and learning mathematics as they are conducting their fieldwork in classroom settings.

It is clear that there is specific knowledge needed to teach mathematics effectively that involves mathematics content and mathematical content pedagogy as well as other areas (Ball, Thames, & Phelps, 2008; Shulman, 1986). The Mathematical Teaching Practices (MTPs) as identified by the National Council of Teachers of Mathematics (NCTM)'s *Principles to Action* (2014) and Mathematical Practices (MPs) for students as identified by Common Core State Standards for Mathematics (CCSS-M, National Governors Association Center for Best Practices & the Council of Chief State School Officers, 2010) support educators in their understanding and implementation of this specific knowledge. NCTM leadership in standards for mathematics has coincided with steady growth in student performance on the National Assessment of Educational Progress (NAEP); however, these standards are only successful if implemented while also addressing classroom instruction and with professional development support (Larson, 2012). The practices that PSTs engage in during their studies must include key mathematical experiences as well as an understanding of and opportunity to develop effective mathematical teaching practices (Conference Board of the Mathematical Sciences, 2012).

Objectives of the Study

The objective of this study was to assess the use of structured vignettes in developing secondary mathematics preservice teacher understanding of effective instructional practices. The following research question was crafted to address the objective: *In what ways does the use of classroom vignettes contribute to secondary mathematics preservice teacher's understanding of effective instructional practices?*

Theoretical Framework

In their conceptualization of an elementary mathematics methods course, Ball, Sleep, Boaerst, and Bass (2009) focus on identifying "high-leverage practices," which they define as "teaching practices in which the proficient enactment by a teacher is likely to lead to comparatively large advances in student learning" (p. 460). In mathematics, these high-leverage practices support work central to mathematics, help improve student learning and achievement, are utilized frequently in the teaching of mathematics, and apply across different approaches to teaching mathematics. The MPs (CCSS-M, 2010) and MTPs (NCTM, 2014) fit the profile of high-leverage practices.

Novice mathematics teachers often underestimate the complexities of the teaching practice, including the MPs and MTPs. Grossman and colleagues' (2009) developed a framework that outlines three key elements of pedagogies of practices that include: (1) *representations of practice*; (2) *decompositions of practice*; and (3) *approximations of practice*. Situating the MPs and MTPs within Grossman et al.'s framework provides an opportunity for preservice teachers to see and reflect on these high-leverage practices in action. Vignettes provide a means to situate the MPs and MTPs within Grossman and colleagues' pedagogies of practice framework. Jeffries and Maeder (2011) define vignettes as "a specific type of short, descriptive story that describes a problem related to course content in order to stimulate discussion" (p. 162). Vignettes have been utilized in a variety of educational settings to capture how teachers respond to specific classroom scenarios. Walen and Hirstein (1995) utilized vignettes while examining reform practices in the mathematics classroom and found that using vignettes "presents opportunities both to assist students' development and to assess their progress in attaining classroom expectations aligned with the reform movement. Vignette activities open a window on students' perceptions of mathematics and classroom roles" (p. 363).

Methodology

This qualitative case study focused on four preservice teachers (PSTs) enrolled in a secondary mathematics methods course required for their program of study. They were simultaneously enrolled in a field experience course where they engaged in teaching experiences in secondary mathematics classrooms. The participants engaged in a five-step vignette analysis sequence, illustrated in Figure 1, designed by the researchers. The brief description of the process is included here but for more detail see Wilkerson, Kerschen, and Shelton (2018).



Figure 1. MTP and MP Vignette Activity Sequence

In the first step of the vignette activity sequence, the PSTs complete a mathematical task as a homework assignment. Figure 2 is a mathematical task used for one of the vignettes in this study.



The following class period, the PSTs engage in the remaining steps of the sequence. In step two, the PSTs read a vignette designed by the researchers that focuses on the mathematical task they

previously solved with accompanying student work. An example vignette related to the mathematical task in Figure 2, is illustrated in Figure 3.



Figure 3. Best Buy Ticket Vignette (Student Work Adopted from Mathematics Assessment Project, 2011)

For steps three through five, the PSTs complete a recording sheet as they reflect on the vignette. The recording sheet, displayed in Figure 4, includes four questions related to the MPs, MTPs, and classroom practice, as well as research. The PSTs respond to the vignette recording sheet individually during class time. Class time is then spent discussing the vignette and connections to both research and practice.

1) Identify any Mathematical Practices practiced by the students illustrated in the vignette. Provide evidence from the vignette to justify the Mathematical Practices you selected. Please connect your evidence to material/discussions/research discussed in class.	2) Identify any <u>Mathematical Teaching Practices</u> practiced by the teacher that is illustrated in the vignette. Provide evidence from the vignette to justify the Mathematical Teaching Practices you selected. Please connect your evidence to material/discussions/research discussed in class.
3) Which two of the provided student work examples	4) How does reflecting on this vignette inform your own
would you choose to have presented to the class?	practice? What will you take away from this vignette, or
Justify your reasoning, keeping in mind the goal the	what connections can you make to your own teaching or
teacher had for the task.	future teaching?

Figure 4. Vignette Recording Sheet

The PSTs engaged in the vignette activity sequence for four different vignettes with their respective mathematical tasks during the fall 2016 semester. For each iteration of the vignette activity sequence, questions 1, 2, and 4 on the recording sheet remained the same. Because question 3 specifically relates to the student work unique to the mathematical task featured in the vignette, it was modified by the researchers for each vignette.

Data was collected from the vignette recording sheets by the researchers. Responses to the vignette prompts were coded using definitions of MPs and MTPs defined by CCSS-M and NCTM respectively, to examine emerging themes related to PST development in understanding of MPs and MTPs as well as the ability to reflect on current practice. In addition, constant comparison was used by the researchers to analyze the data. Glaser (1978) indicates constant comparison analysis involves identifying recurring events, collecting further data that provide evidence of these recurring events, and describing these events while continually searching for new incidents. Using constant comparison analysis allowed the researchers to compare data from each activity sequence, analyzing the data for similarities and differences.

Results and Discussion

The findings of the study showed mixed results when identifying the MPs and MTPs highlighted in each vignette. In two of the four vignettes, a majority of PSTs were able to correctly identify the MPs and MTPs modeled in the vignette. In many instances, the evidence selected by the PSTs to support their choice of an MP or MTP was vague or revealed a lack of understanding. For example, PSTs assumed that students working a given problem constitutes the MP, "Make sense of problems and persevere in solving them" and the MTP, "Implement tasks that promote reasoning and problem solving." However, as the semester progressed, PSTs improved in their ability to select the appropriate MPs and MTPs documented in each vignette. Results also show that PSTs are able to make strong connections between the vignette and their own teaching practices over the course of the semester. For example, analysis of one vignette indicated PSTs were able to make a strong connection to the importance of understanding conceptual knowledge prior to implementation of procedural knowledge. In another vignette, a PST noticed that the teacher in the vignette missed an opportunity for a teachable moment and explained how she would have addressed this teachable moment in her current fieldwork classroom setting.

Implications

Results from this study have several implications. The researchers have discussed the opportunity to use this sequence as a formative assessment. PSTs have misconceptions concerning what constitutes each MP and MTP; reflecting on the evidence provided by each PST can help the mathematics teacher educator adjust their instruction to address these misconceptions. Using vignettes has also proven effective in the PSTs' ability to highlight situations that emphasize certain MPs and MTPs in their own practice.

The vignette activity sequence described in this study is comprised of two phases. Phase 1, the focus of this study, is conducted multiple times throughout the semester. After the PSTs have become comfortable with the activity sequence, they participate in Phase 2 of the analysis sequence. Phase 2 is a culminating assignment in which the PSTs write a vignette based on their own experiences in their fieldwork. At the end of Phase 2, the PSTs engage in the vignette analysis sequence using their classmates' created vignettes. This process has allowed for additional opportunities for the PSTs to connect the MPs and MTPs to their own practice and initiate a rich discussion over each vignette within the methods course. Feedback from the PSTs has indicated their positive experiences with creating their own vignettes and the desire to engage in this more frequently.

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

Future directions of this project include extending the process to a second mathematics education course that focuses on critical issues in mathematics education. Extending this process to this additional course will allow for the creation and analysis of vignettes that focus on topics in mathematics education that include: motivation, equity and access, assessment, etc. Additional vignettes are under development in order to ensure each MP and MTP is addressed during the PSTs' coursework. The researchers envision the future creation of a vignette bank, accessible to the mathematics teacher educator community for use and additional contributions.

References

- Association of Mathematics Teacher Educators. (2017). *Standards for Preparing Teachers of Mathematics*. Retrieved from www.amte.net/standards
- Ball, D., Sleep, L., Boerst, T., & Bass, H. (2009). Combining the development of practice and the practice of development in teacher education. *The Elementary School Journal*, 109(5), 458-474. doi:10.1086/596996
- Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389-407.
- Conference Board of the Mathematical Sciences. (2012). *The mathematical education of teachers II*. Providence, RI, and Washington, DC: American Mathematical Society and Mathematical Association of America.
- Glaser, B. G. (1978). Theoretical sensitivity: Advances in the methodology of grounded theory. Mill Valley, CA: Sociology Press.
- Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. (2009). Teaching practice: A crossprofessional perspective. *Teachers College Record*, 111(9), 2055-2100.
- Jeffries, C., & Maeder, D. W. (2011). Comparing vignette instruction and assessment tasks to classroom observations and reflections. *The Teacher Educator*, *46*(2), 161-175. doi:10.1080/08878730.2011.552667
- Larson, M. (2012). Will CCSSM matter in ten years? Teaching Children Mathematics, 19(2), 108-115.
- Mathematics Assessment Project. (2011). Best Buy Tickets. Retrieved from

http://map.mathshell.org/tasks.php?unit=HE14&collection=9&redir=1

- National Council of Teachers of Mathematics. (2014). Principles to actions: Ensuring mathematical success for all. Reston, VA: Author.
- National Governors Association Center for Best Practices & the Council of Chief State School Officers. (2010). Common Core State Standards for Mathematics. Retrieved from http://www.corestandards.org/Math/
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14.
- Walen, S. B., & Hirstein, J. (1995). Classroom vignette: An alternative-assessment tool. Teaching Children Mathematics, 1(6), 362-365.
- Wilkerson, T., Kerschen, K., & Shelton, R. (2018). PreService teachers' critical connections to effective mathematical teaching practices: An instructional approach using vignettes. Manuscript submitted for publication.

ENRICHING PROSPECTIVE TEACHERS' UNDERSTANDINGS OF AREA: ADDRESSING PREFERENCES FOR BOUNDEDNESS AND RESEMBLANCE

Michelle T. Chamberlin University of Wyoming

Teachers need conceptually-sound understandings of area measurement; however, misconceptions arise such as preferring area units that resemble and do not cross the boundary of a region to be measured. As part of a lesson experiment, prospective teachers (PSTs) measured the area of an irregular region using various shapes as area units. The PSTs recognized that area units need to 'fit together', yet still demonstrated resemblance and boundedness with angled regions. In future lessons, PSTs should use transparency grids of various tessellated shapes to measure the area of an irregular region, highlighting the advantages of square area units.

Introduction

To assist students with the conceptual underpinnings of area measurement, teachers need a robust understanding of area. However, misconceptions arise in measuring area, for students and teachers alike. One misconception of elementary students is preferring a shape for the area unit that does not cross over the boundary of the region to be measured (e.g., selecting circles to measure the area of a curved region even though circles do not tessellate the plane). As such, students select an area unit resembling a region, rather than square area units (Lehrer, Jenkins, & Osana, 1998). We found that prospective teachers (PSTs) also exhibit such preferences in selecting area units (Chamberlin & Candelaria, 2018). Thus, I decided to undertake a *lesson experiment* in my undergraduate mathematics class for elementary education majors to further investigate these preferences amongst PSTs.

Purpose of the Study

For a lesson experiment, a teacher-researcher engages in cycles of testing hypotheses about cause and effect relationships between teaching and learning (Hiebert, Morris, Berk, & Jansen, 2007; Hiebert, Morris, & Glass, 2003). The intent is to address, "What did students learn during the lesson, and how and why did instruction impact such learning?" It is composed of four (roughly) sequential steps: 1) state the learning goals, specify hypotheses of how instruction may attain these goals, and plan the lesson; 2) gather and analyze evidence of students' learning during the lesson; 3) evaluate the hypotheses for why the lesson did or did not achieve the learning goals; and 4) revise the current or future lessons accordingly. The purpose of this study was to use a lesson experiment to examine PSTs' understandings of area units during and after an associated lesson, to evaluate how and why the lesson impacted the PSTs' understandings, and to revise the lesson as needed.

Related Literature: Selecting Area Units

Through interviews with 1st-3rd grade students and a 3-year study of teaching and learning geometry in several second-grade classrooms, Lehrer and his colleagues examined the preferences of elementary students in selecting area units (Lehrer, et al., 1998; Lehrer, Jenkins, & Osana, 1998). The students tended to treat the boundaries of the regions to be measured as absolute (not wanting the area units to cross the boundaries of the given regions), hereafter referred to as *boundedness*. As a result, the students typically selected area units that resembled the region being measured (*resemblance*), even when such area units failed to be congruent or to tessellate the plane. For example, when one teacher asked her second grade students to rank-order the 'amount of space' covered by each of their hands, they selected area units such as beans because they resembled the contour of a hand (Lehrer, et al.). Even after discussion of how the beans 'are not all the same [size]' and 'leave cracks', the students still initially rejected the teacher's suggestion to use an overlay of square units to measure the area of their hands.

In a previous lesson experiment on area and volume, we (Chamberlin & Candelaria, 2018) unexpectedly found that PSTs also exhibit boundedness and resemblance preferences. When asked on a post-assessment item to describe the pros and cons of using squares, circles, and trapezoids for area units, over three-fourths of the PSTs revealed a strong desire for resemblance between the area unit and the region being measured. The PSTs were more concerned about the gaps that would result when an area unit did not line up with the boundary of the measured region than with the gaps that would result with a non-tessellating area unit. This unexpected finding fueled the desire to undertake the present lesson experiment. In planning the current lesson experiment, I was guided by Lehrer, Jaslow, and Curtis' (2003) instructional recommendation that students compare the space covered by an irregular region while provided with various shapes that may be used as area units, including some with curvature. When students compare their measurements, they will likely be upset about the many different resulting measurements from the various area units. This may be used to discuss the need for congruent, space-filling units and the advantages of square area units.

Methodology

I conducted the lesson experiment in an undergraduate geometry and measurement class for elementary PSTs with 31 enrollees. My learning goals were for the PSTs to understand that area is measured by counting the number of squares that cover a two-dimensional closed region and to appreciate the advantages of measuring area with square units (congruency, tessellate, and ease of partial units), thereby letting go of boundedness and resemblance. My instructional hypothesis was asking the PSTs to measure the area of an irregular region using area units of various shapes would enable them to deduce the advantages and disadvantages of such shapes for area units. Then, an ensuing whole class discussion would ensure the PSTs recognized the advantages of measuring with square area units. Thus, for the main instructional activity, the PSTs worked in groups to measure the area of an irregular region using rectangles, trapezoids, circles, squares, and a figure-eight peanutlike shape (see Figure 1). Next, we engaged in a whole class discussion, using PST ideas and input to address issues such as which of the provided shapes tessellate the plane, whether one should select an area unit that resembles the region being measured, and which shapes are more amenable for using partial units. For evidence of the PSTs' thinking during and after the lesson, I collected each group's written work on the class activity, video-taped the whole class discussion, and collected from all PSTs a formative assessment (see Figure 2).



Figure 1. Class Activity completed by the PSTs at the beginning of the lesson experiment.

Formative Assessment

- 1. A circle can be used as an area unit when measuring objects with rounded edges. True or False? Include an explanation with a drawing for your choice.
- 2. A square area unit would NOT work well for measuring the area of the following shape. True or False? Include an explanation with a drawing for your choice.



Figure 2. Formative Assessment completed by the PSTs at the end of the lesson experiment.

My analysis of the data consisted of two phases, first determining the extent to which the learning goals were achieved and then evaluating the hypotheses and instruction for whether and how they supported the learning goals. For Phase I, I used open coding (Strauss and Corbin, 1998) to analyze the class activity and formative assessment data. For the class activity data, I sorted and then analyzed the groups' written work by each area unit shape, e.g., gathered and analyzed the groups' responses for the rectangle area unit, then their responses for the circle area unit, etc. For the formative assessment data, I analyzed each question separately (#1 and #2). Through open coding, I identified the themes within the PSTs' written work, the frequency of those themes, and the specific groups/PSTs corresponding with each theme. To analyze the video-tape data, I viewed the videotapes, loosely transcribing the discussion. Then, I added a column next to the transcript, noting the mathematical ideas that emerged in the discussion. For Phase II, I first noted instances in which the learning goals were attained by the PSTs and returned to the hypotheses and lesson plans to identify which lesson activities appeared to engender such understandings. Next, I noted instances in which the learning goals were not attained by the PSTs or misconceptions remained. Then, I again turned back to the hypotheses and lesson plans to identify how the lesson activities may have failed to address such issues. These issues pointed to possible instructional improvements.

Results and Discussion: Achievement of Learning Goals and Revising the Lesson

For the non-tessellating area units on the class activity (the peanut and the circle), all groups randomly placed the area units as close together as possible over the Funky Shape. Nearly all groups filled in the remaining gaps with partial units and kept the area units within the boundary. The PSTs explained that the peanuts and circles were difficult for completely covering the Funky Shape, did not "fit together", and left gaps. For the tessellating area units (square, rectangle, and trapezoid), the PSTs began by placing a whole area unit next to one edge of the Funky Shape. Then, they repeated the area unit with the same orientation until doing so would cause the area unit to cross the boundary. If space remained that they could repeat this process along another edge, they did so, orienting the area unit in a different direction. Then, they filled in the remainder of the Funky Shape using partial area units (see Figure 3). For every area unit, nearly all groups used partial units and kept their area units within the boundary. The PSTs reported that the squares, rectangles, and trapezoids "fit together"; however, their boundedness preferences appeared to inhibit them from tessellating the area unit with the same orientation over the whole Funky Shape (see Figure 3). Nearly all groups commented that a disadvantage of the straight-edged area units was that they did not line up with the rounded edge of the Funky Shape. Regarding quantifying partial units, one

group commented that it was hard to quantify partial units of trapezoids, and another group commented it was easier to quantity partial units of squares.



Figure 3. Example of how PSTs covered the Funky Shape with the rectangle area unit.

The whole class discussion began when I asked Anita (a pseudonym) to describe their group discussion on the class activity. She shared that the peanuts and circles were hard to use as area units because they did not have straight edges. I asked if any of the PSTs had heard the term "tessellate". As none had, I explained, "Tessellating is when you can repeat a shape next to itself over and over and it covers and doesn't leave any gaps or have any overlaps." I then asked the class, "Of the shapes that are left, which ones tessellate?" After time to discuss in their groups, Isabel explained that the area units with straighter edges do tessellate, like the rectangles. For the next several minutes, I engaged the PSTs in discussing and making drawings to illustrate how rectangles, trapezoids, and squares tessellate. I then asked the PSTs to discuss, "Are rectangles, squares, and trapezoids equally as good for area units or did you have preferences for some?" When I called on Rosina, she explained that "the rectangles and trapezoids worked best for this particular shape (emphasis added)." Thus, I asked the PSTs, "So, would it be helpful to pick a shape for an area unit based on the shape of the object I am measuring?" After time to discuss in their groups, Zach explained that "squares might be easier because if squares you can cut it in halves, quarters, etc." I then asked, "So, you're saying squares regardless of what your shape looks like?" He responded, "Yes, because it's easier to break up into smaller pieces because like with the trapezoid when I cut it, I wasn't sure if it was a half or a third." I then noticed that class time was running out, so I explained, "Beyond this class, have you ever been asked to measure area in trapezoids before? Guess what we conventionally use?" The PSTs collectively responded, "squares". I concluded my explanation as follows, "And we use squares because squares are uniform, the same length on all sides and because of that uniformity these are at least the easiest shape to take partial units of."



Figure 4. Illustration from one PST showing how squares were oriented differently along the edges.

Table 1.

Summary of PSTs' understandings of area units across the lesson experiment.

Understanding	Class Activity	Class Discussion	Formative	
			Assessment	
Area units need to cover the region without gaps or overlaps.	All understood	Reiterated	All understood	
Area units should tessellate the plane, including a.) fit together without gaps and b.) extend in the same orientation to cover the plane.	a.) All understoodb.) Only 2 groups maintained the orientation of the area units	a.) Reiterated b.) Not addressed	 a.) All understood b.) 63% (19/30) maintained the orientation of the square area units 	
Area units may extend over the boundary of the region. When they do so, we use partial area units to determine the area measure.	Nearly all groups kept their area units inside the boundary. However, nearly all groups did use partial units.	Quickly addressed	66% (20/30) understood.	
We use square area units in part due to the ease of quantifying partial units of squares.	Only 2 groups attended to the ease of quantifying partial units for the different area units	Quickly addressed	5 PSTs remarked about the ease of quantifying partial units of squares	
We use square area units despite the shape of the region to be measured, i.e., we do not select an area unit based on the shape of the region to be measured (resemblance).	All groups demonstrated resemblance preferences	Quickly addressed	All PSTs recognized that circle area units leave gaps; however, 7 PSTs still revealed resemblance preferences with angled regions	

On #1 of the formative assessment, all PSTs explained that circle area units leave gaps between repetitions, and 29 PSTs drew a curved region with approximately equally-sized circle area units inside, demonstrating the gaps that remain. On #2, 25 PSTs explained or demonstrated that squares "fit together". Nineteen of these PSTs repeated the squares often enough to demonstrate how the squares would tessellate the plane and kept the squares oriented in the same direction. In contrast, 5 PSTs demonstrated how the squares may fit together, but oriented the squares in different directions to align with the edges of the pentagon (see Figure 4). Twenty PSTs demonstrated evidence of the need to use partial units of squares for complete coverage. However, some PSTs revealed remaining resemblance and boundedness issues. For example, four PSTs expressed preferences for area units that would align with the edges of the pentagon (such as a triangle), and four other PSTs used only one big square to fill as much of the pentagon as possible without going over the boundary. Table 1 summarizes the PSTs' understandings across the lesson experiment.

At the end of the lesson experiment, all PSTs recognized that area units need to cover the region to be measured without gaps or overlaps and that to do so, such area units must "fit together". Furthermore, all PSTs understood that circles are not a viable area unit because gaps remain. The lesson experiment hypothesis, class activity, and whole class discussion led the PSTs to recognize that area units must "fit together" and assisted the PSTs in relinquishing resemblance preferences for area units with curved regions. In contrast, only 2/3 of the PSTs oriented an area unit in the same direction when covering a region, only 2/3 extended the area unit over the boundary and used partial units accordingly, only 5 PSTs argued that it is easiest to quantify partial units of squares, and 1/3 of the PSTs still demonstrated resemblance preferences with angled regions. As part of the Phase II analysis, I noticed that these four issues were discussed quickly at the end of class, primarily through my commentary rather than PST discussion and exploration. In addition, I was shocked to find how often the PSTs changed the orientation of an area unit. This revealed the PSTs had little to no experience with measuring the area of an irregular region using a tessellated area unit. Thus, my main instructional adjustment is to add a follow-up activity in which the PSTs use transparency grids of tessellated shapes (e.g., a grid of tessellated rectangles, a grid of tessellated trapezoids, a grid of tessellated triangles, and a grid of tessellated squares) to lay over and measure the area of the Funky Shape. Upon trying to determine a precise area measure of the Funky

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

Shape, it is expected that the PSTs will encounter the challenges of quantifing partial units and thereby realize that while still sometimes difficult, it is easiest to quantify partial units of squares.

The purpose of this lesson experiment was to examine the impact of instruction on PSTs' understandings of area units. Results indicated that after measuring an irregular region with area units of various shapes (Lehrer, Jaslow, and Curtis, 2003), the PSTs recognized the need for area units to "fit together", letting go of the resemblance preference for circle area units with curved regions. However, only about 2/3 of the PSTs realized that area units may extend beyond the boundary of a region, that area units should be oriented in the same direction, and that squares serve as the best area unit, even for angled regions. Furthermore, only a few PSTs argued that we use squares as the conventional area unit in part because it is easiest to determine partial units of squares. Lesson revisions include adding a follow-up activity in which PSTs use transparency grids of tessellated shapes to measure the area of an irregular shape.

Implications

A few implications and directions for further work may be noted. First, as described in the literature review, grade K-12 students often demonstrate resemblance and boundedness preferences. It is expected that the instructional recommendations proposed here may be applicable for younger students as well. Second, an important part of the lesson experiment process is to replicate the cycle with the revised lesson. Thus, the revised lesson should be enacted to confirm whether the adjustments are actual improvements or just changes to the lesson. For example, one important question to examine is whether the follow-up activity will address the PSTs' preferences for orienting the area units in different directions. Finally, it may be productive to investigate from where students' preferences for boundedness arise. For example, do such preferences come from activities with tangrams or pattern blocks where students are asked to precisely fit smaller shapes into a larger shape? In conclusion, a robust conception of area measurement requires numerous understandings, not the least of which includes a rich understanding of the role of area units.

References

- Chamberlin, M. T., & Candelaria, M. S. (2018). Learning from teaching teachers: A lesson experiment in area and volume with prospective teachers. *Mathematics Teacher Education and Development, 20*(1), 86-111. Hiebert, J., Morris, A. K., Berk, D., & Jansen, A. (2007). Preparing teachers to learn from teaching. *Journal of Teacher Education, 58*(1), 47-61. doi: 10.1177/0022487106295726
- Hiebert, J., Morris, A. K., & Glass, B. (2003). Learning to learn to teach: An "experiment" model for teaching and teacher preparation in mathematics. *Journal of Mathematics Teacher Education*, *6*, 201-222.
- Lehrer, R., Jacobson, C., Thoyre, G., Kemeny, V., Strom, D., Horvath, J., Grance, S., & Koehler, M. (1998). Developing understanding of geometry and space in the primary grades. In R. Lehrer & D. Chazan (Eds.), *Designing learning environments for developing understanding of geometry and space* (pp. 169-200). Mahwah, NJ: Lawrence-Erlbaum.

- Lehrer, R., Jaslow, L., & Curtis, C. (2003). Developing an understanding of measurement in the elementary grades. In D. H. Clements & G. Bright (Eds.), *Learning and teaching measurement: 2003 yearbook* (pp. 100-121). Reston, VA: National Council of Teachers of Mathematics.
- Lehrer, R., Jenkins, M., & Osana, H. (1998). Longitudinal study of children's reasoning about space and geometry. In R. Lehrer & D. Chazan (Eds.), *Designing learning environments for developing understanding of geometry and space* (pp. 137-167). Mahwah, NJ: Lawrence-Erlbaum.
- Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Techniques and procedures for developing grounded theory (2nd ed.). Thousand Oaks, CA: Sage.

DELIJAH'S STORY: OVERCOMING BOREDOM AND REMEDIATION TO MAINTAIN A POSITIVE MATHEMATICS IDENTITY

Thomas Roberts Bowling Green State University otrober@bgsu.edu

Although mathematics identity is becoming more prevalent in the research literature (Jackson & Wilson, 2012), the mathematics identities of elementary students' are rarely given attention, with African American students often being completely ignored. This case study focuses on a third grade African American learner's experience in his mathematics classroom. Although Delijah was an advanced student, his interactions in the classroom lessened his experiences due to the intense focus on remediation. Nonetheless, Delijah excels in the subject and maintains a positive mathematics identity.

Introduction

Mathematics often serves as a springboard or gatekeeper for more advanced study; however, many African American students experience mathematics as a gatekeeper (Martin, Gholson, & Leonard, 2013). Understanding students' experiences in the classroom is critical to better understanding if mathematics is a gatekeeper or gateway. While some argue schools are more responsible than homes for students' mathematics achievement (e.g., Waddell, 2010), all schools are not created equal. Students enrolled in high minority, high poverty schools often experience inexperienced teachers and more remedial courses (Lee, 2004). Delijah, a third grade African American student, attended a high minority, high poverty school. Although his teacher was experienced and rated as highly effective, his negative perceptions of the classroom potentially have long lasting effects for his future mathematics experiences.

Objectives of the Study

The purpose of this paper is to examine how one African American third grade student's classroom experiences influenced his mathematics identity. Interactions between the student, the teacher, and the content were explored for insight into the student's experiences. While the literature on classroom instruction is broad, the focus on African American students' experiences, especially those at the elementary level is limited. This study attempts to provide insight into classroom influences on African American learners' mathematics identities in the elementary years. The primary research question for this study is: How do third grade African American students generate mathematics identities from their interactions with mathematics in the third grade mathematics classroom?

Theoretical Framework and Related Literature

Figured worlds is a framework to examine identity creation in culturally and socially constructed contexts (Holland, Lachiotte, Skinner, & Cain, 1998). Using Vygotsky's (1978) emphasis on individual development through social interactions and Bakhtin's (1981) ideas of authoring and dialogism, figured worlds are specific places (e.g., a third grade mathematics classroom) in which identities are produced over time and based on social interactions. How individuals perceive themselves, others, and interactions in the figured world are important in shaping the figured world and in the identities they create. Interactions and identities that occur in specific figured worlds can carry over into other figured worlds. Identity development can occur through interactions in the figured world due to the variety of experiences individuals possess (Urrieta, 2007).

Three contexts are important within figured worlds for identity formation: positionality, spaces for authoring, and world making (Holland et al., 1998). Positionality emphasizes the role of power and how an individual perceives oneself in relation to others in the figured world. Important positions for this study include smart student and good student. Social categories (e.g., race and class) can provide opportunities or barriers for individuals' positions in figured worlds. Individuals must accept, reject, or negotiate the positions they are offered (Holland et al., 1998).

Space of authoring relies on Bakhtin's (1981) idea of dialogism as individuals' contrasting and competing ideas help shape their responses to the positions they are offered. Responses are often shaped by norms in the figured world and the values of the individual. Moreover, novice members of the figured world are more likely to accept positions offered to them by more powerful actors, whereas more seasoned actors may negotiate unfavorable positions to shape their identities.

While figured worlds provides a framework for analyzing identity development, Martin's (2000) four level framework for influences of African American mathematics identity development is also crucial for this study. Martin (2000) argued African American mathematics identities are influenced by sociohistoric factors (e.g., the ongoing detrimental effects of systematic exclusion), community and parental factors (e.g., expectations and role models), school factors (e.g., norms and classroom experiences), and individual agency. Many studies that focus on African American mathematics identities have explored the community/parent factor and individual agency (e.g., Berry, 2008), but few explore African American students' experiences in the classroom.

Methodology

I used a case study approach with qualitative methods to explore how one third grade African American learner's experiences in his mathematics classroom influenced his mathematics identity. The case study approach allowed me to create a more complete picture of the student's experiences (Berk, 2006) while prioritizing his voice (Nieto, 1992). I used reputational case sampling to identify four potential student participants. All four participants were in Ms. Madison's third grade mathematics class in a large urban elementary and middle school in the United States. The four students were recommended based on what Ms. Madison judged to be their ability to articulate their experiences in the mathematics classroom. Two boys and two girls were recommended. One boy's parents did not consent to his participation. The parents of the three other students consented and the students assented. In this paper, I focused on Delijah, the only male participant.

Delijah was nine years old and the oldest of three siblings. He lived at home with his mother and father who encouraged him to do well in school and held high expectations. In his third grade mathematics class, Delijah completed his assignments and helped others when requested. Ms. Madison, his teacher, described him as an "out of the box" thinker and as a student who had not encountered a problem he could not solve in her class (Madison Interview Transcript).

I used multiple data generation strategies as I explored Delijah's classroom experiences. Participants were given a brief questionnaire that explored their attitudes toward mathematics. On the back of the questionnaire they drew what mathematics means to them. I also used video recordings in two ways: stationary video and camera glasses. The stationary camera primarily focused on the classroom instruction. On computer or assessment days, the stationary camera focused on the three participants. Each participant wore a pair of camera glasses during mathematics class. These glasses allowed for audio and video to be recorded from each student participant's perspective. I used a three-interview series model (Seidman, 2014) with the student participants. In the second interview, I used stimulated recall to explore specific happenings in the classroom. I also interviewed Ms. Madison, the classroom teacher, to get her perspective on the students and to better understand her approach to mathematics instruction.

I conducted data analysis as an ongoing process throughout the study. Generally, I used two strategies, relying on theoretical propositions and examining plausible rival explanations (Yin, 2014). I also used pattern matching, partitioning variables, and making conceptual/theoretical coherence (Miles, Huberman, & Saldana, 2014). When analyzing Delijah's case, rival explanations were incredibly important as his experiences were significantly different from the other participants.

Interviews were audio recorded and transcribed after they were completed. I used memoing as a reflective and analytical process to generate questions for later interviews. I ensured trustworthiness by implementing four strategies. First, I checked for researcher effects by staying

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

on-site for an extended period of time and spreading out site visits (Miles, Huberman, & Saldana, 2014). Second, I triangulated the data by using multiple sources of data and using different data collection methods. Third, I looked for negative evidence. Finally, I used member checking by having Ms. Madison review my findings for plausibility. From this on-going analysis, two primary themes emerged. These themes are presented in the results and discussion section.

Results and Discussion

Two primary themes arose from the data: Delijah's advanced mathematics abilities created a disillusionment with the mathematics classroom; and, instructionally, Delijah rarely faced the challenges he needed to grow in the mathematics classroom. Delijah associated mathematics with rote skills (see Figure 1), which worked well with Ms. Madison's classroom. Based on traditional assessments, the majority of the students in Ms. Madison's classroom were performing below grade level. The curriculum Ms. Madison used focused primarily on rote skills and procedures, one of the obstacles identified by NCTM (2014) to achieving the Access and Equity Principle. Unfortunately for Delijah, he already had a strong grasp on the rote skills and procedures being taught in his mathematics class.



Figure 1. Delijah draws what math means to him, showing an emphasis on basic skills and procedures.

During his stimulated recall interview, I asked Delijah to explain what was happening in several scenarios. After he said he was not learning mathematics in the first three instances, I probed for more information.

I: If you're not learning math when you're doing the counting and the sprints and you're not learning math on the computer, then how do you learn math?

D: At home.

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

I: So you learn most of yours at home. Do you learn any in the classroom? D: No.

I: So you don't really learn in the classroom. Tell me about what you do at home then. D: Stuff that we do at school... I use my computer... My mama puts me on a website. (Delijah stimulated recall interview transcript)

While Ms. Madison was giving different strategies for multiplication through skip counting and focusing on fluency with sprints, Delijah already knew his multiplication facts. His mother's help at home ensured he had a firm grasp on the basics. He knew he understood the material being taught which led to his boredom with the different strategies presented. Consequently, there were times when Delijah found himself doodling in class only to fill in answers when given the information as a whole group. His grades were good. He got most answers correct. Therefore, for Delijah, he was a good mathematics student. Unfortunately, he did not associate his time in the classroom with learning mathematics. In the future, his disillusionment may lead to a change in his mathematics identity as Boaler and Greeno (2000) noted many high school AP calculus students who do not see the value of their mathematics class do not pursue further mathematics study.

Instructionally, Ms. Madison recognized the challenges she faced. Many of her students needed extra help. She worked diligently to provide students with multiple representations and multiple strategies. In many of her lessons she explicitly discussed how they were using the Standards for Mathematical Practice. Nonetheless, Delijah was disillusioned. Delijah did not understand the purpose of many of Ms. Madison's methods. To him, he already understood the material. He could solve problems and get the correct answer. He already knew the materially, at least instrumentally. The tension between instrumental and relational understanding (Skemp, 2006) was always at play.

I asked Ms. Madison for her insights into her students. She described Delijah as an "excellent student" with a "brilliant mind" (Madison Interview Transcript). When asked about how Delijah responds when he faces a problem he cannot solve, Ms. Madison explained they "had not ran into something he [hadn't] understood" (Madison Interview Transcript). Although he excelled in her classroom, she described his ability as innate; moreover, because he is rarely challenged, she noted he had a more fixed mindset about mathematics. Thus, one major challenge for Ms. Madison was serving the diverse needs of her students. She provided high quality instruction for the majority of her students; however, she had not found a way to challenge Delijah in a way that he associated with learning mathematics.

Delijah's experiences were similar to those of successful middle school African American boys as described by Berry (2008). He was fluent in his facts. He had strong parental expectations and support. At the same time, Delijah's experiences raised concerns for his future experiences. While he said he enjoyed his mathematics class, he consistently reiterated he was not learning; moreover, he often appeared bored with the tasks he completed in class. Consequently, he did not associate his mathematics class with learning mathematics, even while he maintained his position as a good math student. This position was reinforced through his interactions with Ms. Madison, through his consistent ability to arrive at the correct answer, and through his grades. This position was easy for Delijah to accept as it aligned with his own view of himself as a good mathematics student. Delijah's future, however, is not guaranteed to have effective teachers to reinforce his status as a good mathematics student. Delijah's school was high poverty, high minority. As such, he is more likely to have teachers who are less qualified, less experienced, and less effective (NCTM, 2014). If Delijah continues to disassociate classroom mathematics with learning mathematics in an environment where he has less than adequate mathematics teachers, he may no longer be able to accept the position of good math student that coincides with his positive mathematics identity. When he is forced to negotiate his position, his mathematics identity may be challenged.

Implications

While Delijah's story is just one student's experience in one elementary mathematics classroom, his story gives us many important lessons. Delijah overcame his regular boredom and the lower level material to maintain his positive mathematics identity. Delijah had always been an honor roll student. He knew he was good at math when he entered third grade. Nothing in Ms. Madison's class changed that. However, Delijah was not challenged. The focus on skills he already understood led him to the belief that he did not learn mathematics in his mathematics class. One major implication of this study is the importance of enrichment in urban schools. While much effort is focused on remediation, students like Delijah also need to be challenged so their learning does not stagnate. What if Delijah's parents did not have high expectations and provide him with additional mathematics learning outside of school? There is no way to know how Delijah's experiences would be different had he not have had the parental support.

A second implication of this study is the importance of school level support for classroom teachers. Ms. Madison was not the unqualified, inexperienced teacher with low expectations that many students in high poverty, high minority schools experience. Ms. Madison provided multiple representations of solutions. She gave students multiple strategies. She emphasized the Standards for

Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

Mathematical Practice in her instruction. Nonetheless, Delijah said he was not learning mathematics in her classroom. While many schools focus on remediation and supporting those students who struggle, the same supports are not available to students who are performing at or above grade level. Classroom teachers need help to ensure all students are receiving the instruction they need, not just those students who need additional support to catch up.

Finally, Delijah's story is a cautionary tale. Delijah had a good third grade mathematics teacher. He did well by traditional measures, namely grades. His parents, especially his mother, were supportive and encouraging. Yet he had an underwhelming experience in his third grade mathematics class. More research is needed to not just look at the impact of pedagogy (e.g., Boaler & Greeno, 2000), but also how successful students respond to adversity as they continue their mathematics education. Delijah maintained his positive mathematics identity through his boredom and through significant remedial content because his teacher positioned him positively as an advanced student. Delijah's ability to excel in Ms. Madison's classroom may not translate to success in another teacher's mathematics classroom. For instance, another teacher may see his doodling as a lack of effort and challenge his position and positive mathematics identity. Understanding how Delijah and students in similar situations respond to these situations is an important direction for future research.

References

Bakhtin, M. (1981). The dialogic imagination. Austin, TX: University of Texas Press.

- Berk, L. E. (2006). Child Development (6th Ed.). Upper Saddle River, NJ: Pearson Education, Inc.
- Berry III, R. Q. (2008). Access to upper-level mathematics: The stories of successful African American middle school boys. *Journal for Research in Mathematics Education*, 464-488.
- Holland, D., Lachiotte, Jr., W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.
- Jackson, K., & Wilson, J. (2012). Supporting African American students' learning of mathematics: A problem of practice. Urban Education, 47(2), 345-398.
- Lee, C. (2004). Racial segregation and educational outcomes in metropolitan Boston. Cambridge, MA: The Civil Rights Project at Harvard University.
- Martin, D. B. (2000). Mathematics success and failure among African-American youth: The roles of sociohistorical context, community forces, school influence, and individual agency. Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.
- Martin, D. B., Gholson, M. L., & Leonard, J. (2010). Mathematics as gatekeeper: Power and privilege in the production of knowledge. *Journal of Urban Mathematics Education*, 3(2), 12-24.
- Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd Ed.). Thousand Oaks, CA: SAGE Publications, Inc.
- National Council of Teachers of Mathematics. (2014). Principles to Actions. Reston, VA: NCTM.
- Nieto, S. (1992). Affirming diversity: The sociopolitical context of multicultural education. White Plains, NY: Longman.
- Seidman, I. (2006). Interviewing as qualitative research: A guide for researchers in education and the social sciences (3rd Ed.). New York, NY: Teachers College Press.
- Skemp, R. R. (2006). Relational understanding and instrumental understanding. Mathematics Teaching in the Middle School, 12(2), 88-95.
- Mohr-Schroeder, M. J., & Thomas, J. N. (Eds.). (2017). Proceedings of the 116th annual convention of the School Science and Mathematics Association (Vol. 4). Lexington, KY: SSMA.

- Urrieta, Jr., L. (2007). Figured worlds and education: An introduction to the special issue. *The Urban Review*, *39*(2), 107-116.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.
- Waddell, L. R. (2010). How do we learn? African American Elementary students learning reform mathematics in urban classrooms. *Journal of Urban Mathematics Education*, 3(2), 116-154.
- Yin, R. K. (2014). Case study research: Design and methods. Thousand Oaks, CA: SAGE Publications, Inc.

Read the latest research on Science and Math Education from Wiley



wileyonlinelibrary.com/subject/education

