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About the Journal

Founded in 2013, the Journal of Teacher Action Research (ISSN: 2332-2233) is a peer-reviewed online journal indexed with EBSCO that seeks practical research that can be implemented in Pre-Kindergarten through Post-Secondary classrooms. The primary function of this journal is to provide classroom teachers and researchers a means for sharing classroom practices.

The journal accepts articles for peer-review that describe classroom practice which positively impacts student learning. We define teacher action research as teachers (at all levels) studying their practice and/or their students' learning in a methodical way in order to inform classroom practice. Articles submitted to the journal should demonstrate an action research focus with intent to improve the author's practice.

Editorial Team

MAINTAINING SCIENTIFIC LITERACY IN A DIGITAL AGE: THE TRANSITION OF A HIGH SCHOOL BIOLOGY CLASS FROM PAPER TEXTBOOKS TO DIGITAL TEXT RESOURCES

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Abstract At the start of the 2017 school year, administrators at the high school where I am a teacher, implemented a switch from paper textbooks to free, digital resources (that include texts) for all incoming freshmen students. Both my 9th grade on-grade-level Biology students and I unexpectedly found ourselves at the dawn of the Digital Education Age. For me, that meant the elimination of paper textbooks from my curriculum, and therefore the loss of the primary resource I had that students used to practice and develop close technical reading skills. All of the studies that I have read on reading show that students lose literacy when reading on a screen versus paper. However, this paper will describe the journey of my students and me as we developed and implemented digital reading strategies to maintain the level of scientific literacy that former students were capable of reaching through the use of paper textbooks. Most agree that modern education is swiftly moving in the digital direction. This paper is a call to secondary teachers who must recognize that the emphasis on content memorization is diminishing while the emphasis on scientific literacy is expounding, that relying on videos and interactives to teach content ignores the student's need to practice scientific literacy skills, and that teachers of any level or subject must use digital reading strategies to train students to read mindfully in order to combat the significant dip in literacy the digital world presents.

Keywords: teacher action research, textbook, scientific literacy, digital text

Introduction

Although "literacy" is defined as the ability to read and write, "scientific literacy" is defined in part as someone who can "read articles with understanding of science in popular press and engage in social conversation about the validity of conclusions" (National Science

Education Standards, 1996). In this present time period, scientific literacy may be one of the most important skills a person needs to develop in order to have success in their personal life and their career. As Neil deGrasse Tyson states: "Part of what it is to be scientifically-literate, it's not simply, 'Do you know what DNA is? Or what the Big Bang is?' That's an aspect of science literacy. The biggest part of it is do you know how to think about information that's presented in front of you" (Gardinier, 2017). Wolf (2018) noted that traditional paper textbooks were set up to foster thinking, but digital content is not. If members of our society, especially leaders of our society, do not develop the ability to think about information presented to them, then, as Mr. Tyson states, "...you are not a participant in the future of the world" (Gardinier, 2017).

In order to both reduce the annual budget and to justify the district's 1:1 technology initiative, the Board of Education overseeing the school where I work decided that beginning in the 2017-2018 school year, no new print textbooks would be purchased, and none should be given out to either the freshman or sophomore classes (those with chromebooks). Teachers were instructed to only use digital textbook resources. The Science Supervisor at the district specifically directed science teachers to begin using the CK-12 resource created by the CK-12 Foundation (CK-12 Foundation) and the specific use of the Biology text on that site (Brainard et al., 2017).

I immediately questioned this initiative from a standpoint of scientific literacy. I regularly use many online resources in my classroom as content-specific supplements to the paper textbook and noticed a trend among students to not read any digital articles they were assigned. For example, if I assigned an online article and gave a homework sheet to go along with it, students scanned the questions on the homework sheet and looked for keywords. They used shortcuts, primarily the "find" shortcut ("CTRL + F"), which prompted the computer to scan the entire article for that single keyword. Then, the student just read a few sentences around that keyword to find the answer to the question. More often, students avoided reading the article, and had a difficult time discussing it in class the next day. These kinds of shortcuts were not possible with printed material, and students had been more likely to read their paper textbook and were more successful in discussing what they read when they came to class the next day. My deep concern was that by eliminating the only Board-approved resource I had that promoted scientific literacy and replacing it with something online that is so easily "searchable," students were going to lose their scientific literacy skills.

And therefore, I have come to the genesis of my question. In this changing educational climate, how could I use the mandated CK-12 online textbook in such a way that scientific literacy was not lost? How could I best use this resource to encourage comprehension of big ideas and overarching concepts? In short, how could I ensure that students are *reading* the entire passage?   As many other schools across America are experiencing similar change, I believe this question is on the minds of many teachers, and those at the start of this journey will benefit from my experience.

Literature Review

Traditional Reading Strategies Do Not Translate To Digital Media. In 2007, Wolf published "Proust and the Squid," a history of the science and development of the reading brain from antiquity to the twenty-first century. Her core observation was that "human beings were never born to read," and that reading is not genetically acquired, it is a human invention that must be taught (Wolf, 2007).   The responses she received to the book overwhelmingly carried one theme: the more reading moved online, the less students seemed to understand. She explored this theme in her follow-up book, noting that the strategies employed for deep reading, and developing a connection to the material, are not to be found in digital media. She aptly titled this book, "Reader, Come Home," encouraging a return to paper books (Wolf, 2018).

Differences Between Print Text and Digital Text. The following contemporary research echoes Wolf's findings. For example, Anne Mangen's group noted that reading involves the ergonomics and haptics of the medium - the tangibility of paper versus the intangibility of something digital. The screen seemed to encourage more skimming behavior, and people read more quickly (and less deeply) than when paper was used. Online reading with embedded links, videos, and interactives had such an overload of information that people read more quickly (and less deeply) to compensate (Mangen et al., 2013). Ziming Liu (2005) found that on screen, people tended to browse and scan, to look for keywords and to read in a less linear, more selective fashion. However, on paper, readers concentrated more on following the text. Skimming online lead to the inability to stop and draw one's own conclusions. Dyson (2004) described how online readers became fatigued easily by the constant need to filter out hyperlinks and other distractions, and that the eyes themselves became fatigued from the constant shift in screen layouts, colors, and contrasts. From these experts, Konnikova (2014) found digital reading to be superficial and exhausting.

Comparing Comprehension (Paper versus Digital). In my classroom, I was focused on how the newly implemented digital biology textbook would compare to the print one in both comprehension and literacy. Mangen (2013) did a study by asking one group to read a short story on paper, while another group read it digitally. They were then asked to place a series of events from the story in chronological order. The print group fared significantly better than the digital group, leading her to conclude that the physical materiality of the paper resource mattered for basic comprehension.

Attention To Reading Tasks (Paper versus Digital). As far as online resources fostering deep scientific literacy, it may come down to a student's self-control. To read an assignment on paper, a student must monitor themselves only once - to pick up the book and open it. To read an assignment digitally, with so many distractions, the monitoring and self-regulation cycle happens over and over. It is predicted that those students who cannot easily focus their attention will experience diminished levels of comprehension and literacy when reading online (Konnikova, 2014).

Why Is Digital Reading Popular? In my research of the literature, I could not find any counter arguments that would give evidence for digital reading being better for student comprehension. So with expert consensus being that reading digitally is not as beneficial for a student as paper was, why is education trending in this direction?   In research done by Wallis (2017), she noted that when students were asked if they read better in print or digital media, they would overwhelmingly respond that they did better in digital media. She found this very odd as her research showed they were not "reading better." Wallis argues that the students are equating "reading better" with "reading faster" and assuming that because they were reading faster that they understood it better.

Digital Reading Strategies. Without having ever learned any digital reading strategies myself, I only thought to apply those which had been successful for me on paper, and which I found to be easily available on the CK-12 website - coded highlighting and annotation. Schwartz (2016) wrote in, "Strategies To Help Students 'Go Deep' When Reading Digitally," ways that students can utilize the tools available in a Google Doc. It is important to note that he makes the students do the work of coded highlighting, annotation, and outline development, rather than using a computer program that will do that for the student (Schwartz, 2016). This is exactly similar to doing what can be done on paper (although not in school-issued books), but was done digitally, and was very effective. For my work here, I aimed to follow Hess's initiative - use available reading strategies, and make the students do the work when reading.

Methodology

Participants. In the 2017-2018 school year, I was in my sixth year teaching at a small rural, non-diverse public high school in New Jersey. It is one of only 18 public International Baccalaureate World High Schools in New Jersey (Iborganization, 2018). In 2018 the school ranked within the top 20 high schools in New Jersey (Schlager, 2018). I taught three sections of on-grade-level freshman Biology for a total of 58 students, the majority of which had a variety of accommodations for learning differences. All of these students received a chromebook, and this was my first time not assigning a paper textbook to these classes, as per my school board's decisions.

Question. With the elimination of the paper textbook and the adoption of the digital online textbook, my research question is clear: How could my students and I (as their teacher) use reading strategies in a digital Biology textbook to enhance comprehension while maintaining scientific literacy?

Data Tools. Before looking at the CK-12 site, I sent out a survey to the 140 teachers in the district to gauge their level of comfort in assigning and using digital textbooks. I was hoping to find some respondents who would be able to guide me through my own switch to this new resource. I next set out to survey my sixty incoming freshmen Biology students, to discover whether they preferred print or digital textbooks and to let their responses guide my education and implementation of new digital reading strategies.

I kept a journal throughout the research, and interviewed my supervisor, the CEO of the digital textbook assigned to me, and spent numerous hours with my co-teacher refining the resource and ensuring that the students would have a beneficial reading experience. With daily collaboration and reflection, I was able to develop a reading experience that I felt maximized the skills of scientific literacy.

Finally, I wanted to compare test scores from 2016 (paper textbooks) with 2017 (digital text resources) to ensure that students being given the new digital medium could perform as well on assessments as prior classes.

Results and Discussion

Twenty-seven teachers responded to the teacher survey, representing a roughly equal distribution of grades taught (33.3% 9th grade teachers, 29.6% 10th grade teachers, 22.2% 11th grade teachers, and 14.8% 12th grade teachers). My first question to those teachers was, "Have you replaced your paper textbook with a digital textbook?" The results are shown in Figure 1. This figure indicates that two-thirds of teachers have or will be switching to digital textbooks, while one-third do not plan on doing so now or ever.
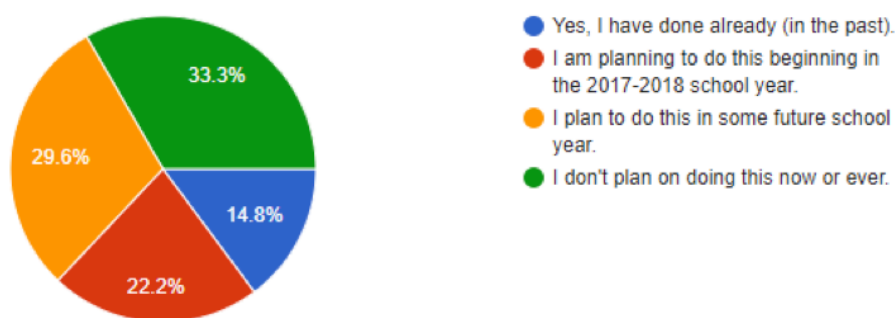
Figure 1: Teacher responses to the question, "Have you replaced your paper textbook with a digital textbook?"

Sixteen teachers responded to the survey that they were switching to digital textbooks that year, as I was, or planning to switch in some future year. I was most interested in the responses from this group. Most in this group responded that they were making the switch because their "supervisor told them to." This group reported that digital textbooks have many advantages including ease of access, interactives, and videos. When asked which medium provides the best level of literacy for students, the majority of this group felt the level of literacy would be the same, no matter which resource is used. Thirty-eight percent of respondents in this group reported that they have no idea what kind of digital reading strategies they should be modeling or teaching. As this was the crux of my research question, I found this incredibly jarring, and an indication that administrators don't fully understand the impact of their decisions on the students, as they aren't adequately

preparing the teachers for actually using the new resource. As a high school Biology teacher, I had never modeled or taught reading strategies, and it appears that most teachers at my high school have not done so either, and certainly not in a digital format. I still believed that being scientifically literate was an essential skill, but I realized I would be navigating the digital reading strategies world without peer support.

Student Preparedness. I surveyed my students before introducing them to the CK-12 textbook resource to be used in this class. The results are shown in Figure 2. This figure indicates that 36.7% of students prefer paper, while 35% preferred digital, and the remaining 28.3% were undecided or do not use textbooks.
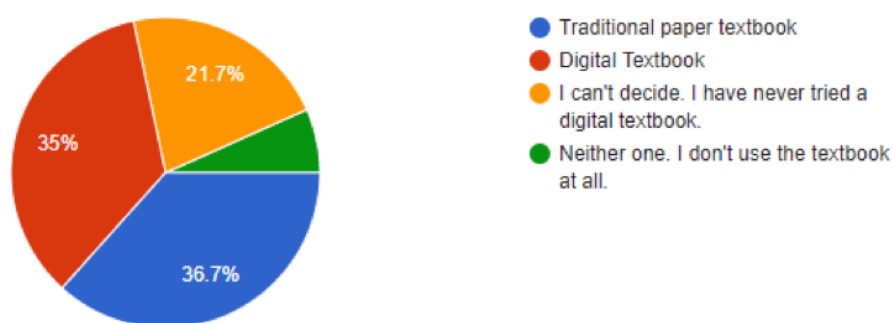

Figure 2: Student responses to the question, "Do you prefer a traditional paper textbook or do you prefer a digital textbook?"

Students were about evenly split between preferring either the paper textbook or the digital textbook. In the group that preferred paper textbooks, one comment was, "I enjoy reading while not using the screen, and turning the pages is just a good feeling, feels more accomplishing when you finish a reading." This group also felt very strongly about their dislike for digital textbooks, commenting "they suck," "because I stink with technology," "technology hates me," and "because I always work better on paper." Many students felt that looking at a computer too long gave them eye strain or a headache. They overwhelmingly felt that they were more scientifically literate when using paper textbooks, and 20 out of 22 students have already been taught and regularly use reading strategies such as highlighting, annotating in the margin, and taking notes with their paper assignments.

In the group that preferred digital textbooks, they responded that, "there is no need to flip page after page after page," "because my backpack cannot fit any more books," and "I've never liked just having one resource to look through, with digital I can look through many different resources and compare." This group did not like paper textbooks because, "they are too heavy and get lost," "it takes forever to find stuff," and "it is really obnoxious and big and it makes me dread wanting to read it." Not surprisingly, this group thought that text presented digitally maximized their scientific literacy, and 16 out of 21 used the same on-paper reading strategies as the previous group.

Armed with the information that I would be making the switch to the CK-12 resource essentially on my own and knowing my students had used reading strategies with paper in the past, I made it my goal to figure out how to best use the CK-12 digital textbook resource to enhance my student's comprehension of Biology content, and enhance their scientific literacy.

Unpacking the Resource: Problems. On September 1, 2017, I began working with the CK-12 resource. The previous year's textbook was the Holt *Biology* textbook (Johnson and Raven, 2004) and lessons can be compared to what is found in the CK-12 resource. If I were to just use the link provided, I find, as I noted in my journal of September 1, 2017, "the link takes me to a web page that contains so much reading that if I were to print it out, it would be 16 pages! There is so much reading, and so many concepts introduced at once, and more depth than I can go into in an on-grade-level class that I think it is too much for my students to handle." This resource bills itself as an on-grade-level resource, but I found that the depth, breadth, and length of this reading was far beyond what my students can handle. In addition, the link provided would allow students to highlight and annotate as they read - but without a CK-12 account, their work would not be saved. And what is the point in that?

A Review of Previous Practice. In my past years as a teacher utilizing paper textbooks, I was able to ensure students were deeply reading the resource by assigning short sections (approximately three pages) to read, and assigning a worksheet of my own design that asked questions about what they had read. The feedback I got from students and other teachers was that the worksheet forced students to slow down and carefully read the textbook. Students who did this work were fully prepared to participate in discussion the following day. After being assigned a digital textbook to use, and reviewing the relevant literature about the lack of scientific literacy with this type of media, I set about to radically change my approach to reading homework.

Unpacking the Resource: Solutions. After about 20 hours of working with the CK-12 resource, I had my first unit ready to assign to the class - text reading only, in chunks, capable of being highlighted, annotated, and saved. I worked with the resource until, to the best of its ability, it would provide the reader with all of the tools necessary to read deeply. I limited the distractions as much as possible by assigning small chunks of text to read. Following the directions on the CK-12 website, I created a digital classroom so that my students could save their digital highlighting and annotations. Unfortunately, this new look meant that it took my students seven clicks to get from our class website out to the CK-12 text reading. It was so confusing my co-teacher made a checklist for the students. On the back of the checklist, I put the coded highlighting key I wanted the students to use: yellow for vocabulary, green for concepts, and blue for examples. One positive aspect is that once the students finish their coded highlighting assignment, the program collates all of the colors at the bottom - creating a vocabulary list, a concepts list, and an examples list. The bad part is that as the teacher on the CK-12 site, I can only see a checkmark when students "Turn In" their reading. I cannot see what they highlighted.

I guided the students through their first reading assignment during class time. Students were able to log on, follow the checklist, and read the selection while highlighting only the relevant information. In my journal, I noted that students who initially preferred a paper textbook were excited that they could highlight because paper textbooks were expected to be returned in the condition they were handed out in, and marking one up was seen as a bonus.

I felt confident enough to ask my students to do this work in the future as a homework assignment. I set up the digital reading sections in advance, and assigned the reading to the students. However, without the resource easily accessible, the percentage of students doing the work started to plummet (see Figure 3). This figure indicates that 95% of students did their "Science Goals" reading assignment, but only 64% completed the "Scientific Investigation" reading assignment.
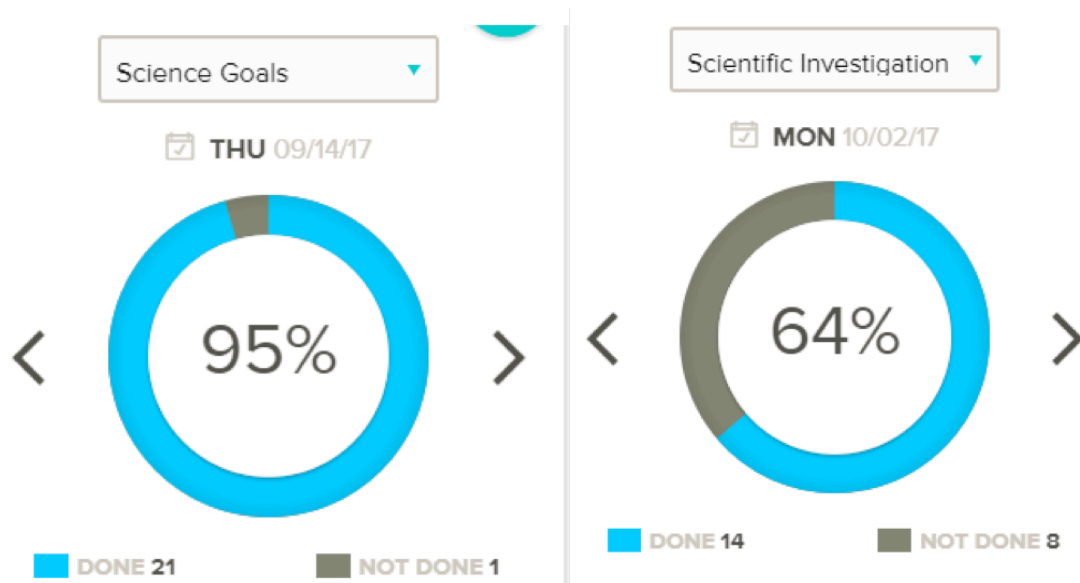
Figure 3: Percent of reading assignments "turned in" for two readings: "Science Goals" and "Scientific Investigation" (CK-12 Foundation).

A way to address this loss of literacy came unexpectedly in November. I was out sick and designed a substitute lesson that could only be completed if the homework reading had been done. When I returned to class, I asked students to fill out an exit pass letting me know if they ran into problems doing the work because of unpreparedness. I found that students were very quick to recognize the role that reading played in their academic success, as they were unable to contribute when unprepared, but more so, they felt the negative emotions from their peers as they were unable to pull their weight in the group activity. Thirty-nine percent of students admitted to not doing their reading, and their responses ranged from the knee-jerk, "I didn't know we were supposed to read the online textbook," to the more deep and reflective, "We didn't use it. But we'll start!"

Final Impressions. I ended my research time with the one piece of data I was most concerned about - student success. In late November, I conducted a survey of my students to see how they felt about their reading skills and ability to be successful in my classroom. At the beginning of the school year, I had asked my students which type of media they preferred for reading, and after three months of using the CK-12 resource, I asked the same question again. Figure 4 shows the responses to both questions. This figure indicates that students preferring to read digitally jumped from 35% in August 2017 to 69.8% in November 2017. Of 34.8% of students not using digital textbooks in August, now preferred them in November.
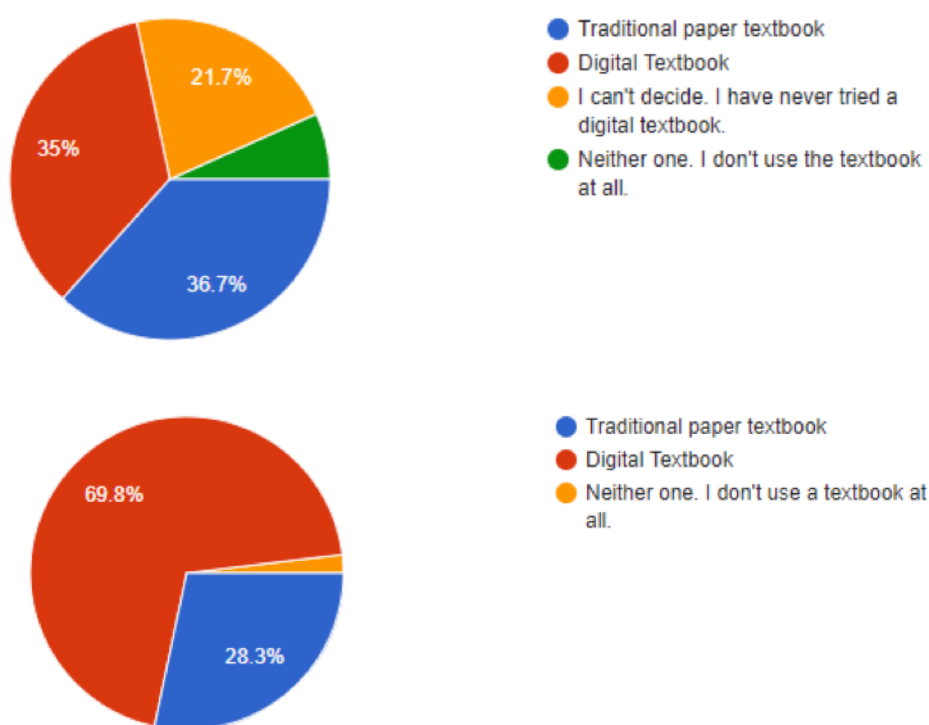
Figure 4: The change in student preference for text reading from August 2017 to November 2017.

The responses indicate that the number of students who preferred a paper textbook to a digital textbook had dropped from 36.7% in August to 28.3% in November, while digital preference nearly doubled from 35% in August to a staggering 69.8% in November. The Chi-Square test for statistical significance was used to evaluate the results and with a X^2 value of 32.52 with one degree of freedom, I can conclude that the differences in these numbers represents a true change in student preference ($p < 0.05$). However, the question was answered based on student preference for text media (i.e., what they thought they liked best). I recalled from Wallis's (2017) research that psychologically students equated reading faster on a screen with reading better, when in reality they were retaining less information than if they had read the same text in print. To explore whether this was happening with my class, I compared my current year students' average test scores across the three tests

that they have taken so far this year with the previous year's student scores. Of course, the unit incorporated lecture notes, activities, experiments, projects, and demonstrations as well, but all resources used were the same as last school year - with the only change being the textbook. The test used was exactly the same. See Tables 1, 2, and 3 for a summary of test scores across three periods of Biology. Table 1 shows that there was no significant difference in the test scores of any period over two years ($p < 0.01$). Table 2 shows that there was no significant difference in the test scores of any period over two years ($p < 0.01$). Table 3 shows that there was no significant difference in the test scores of any period over two years ($p < 0.01$).

Table 1: The average "Themes of Biology" test scores for each period of Biology in two school years (total point value of test equals 80 points).

	Period 1	Period 2	Period 7
Average Test Score For 2016-2017 School Year (Paper Textbook)	67.5	62.2	65.8
Average Test Score For 2017-2018 School Year (Digital Textbook)	63.3	67.3	76.1

X^2 value = 2.29; df = 2; $p < 0.01$

Table 2: The average "Inorganic Chemistry" test scores for each period of Biology in two school years (total point value of test equals 55 points).

	Period 1	Period 2	Period 7
Average Test Score For 2016-2017 School Year (Paper Textbook)	43.1	41.4	41.3
Average Test Score For 2017-2018 School Year (Digital Textbook)	39.1	40.8	41

X^2 value = 0.38; df = 2; $p < 0.01$

Table 3: The average "Organic Chemistry" test scores for each period of Biology in two school years (total point value of test equals 70 points).

	Period 1	Period 2	Period 7
Average Test Score For 2016-2017 School Year (Paper Textbook)	59.2	59.5	54.4
Average Test Score For 2017-2018 School Year (Digital Textbook)	54.5	59.1	53.2

X^2 value = 0.40; df = 2; p < 0.01

Here again, the Chi-Square Test of Statistical Significance was used to evaluate the results. On each test, and for each period of Biology, I am confident that there is essentially no difference between the test scores of these two groups. The students' perception of doing well with digital media is accurate - they are doing at least as well as their peers who were taught with a print textbook. There has been no loss of literacy skills in my classroom, despite the switch to digital textbooks.

Figure 4 clearly shows that 34.8% of my students who initially did not feel successful with a digital textbook by November were using the digital textbook effortlessly and felt successful. I wanted to explore some of the reasons that brought about that change. First, I asked the group that preferred the CK-12 resource what it was that they liked about CK-12 that made it better than their previous paper textbooks. Twenty-two out of the thirty respondents in this group chose "highlighting" as the main improvement over paper textbooks, for example writing, "it's easy to get to the article, and the article is all together. no turning pages, no getting lost, easy highlighting, automatic notes. It makes the whole studying process 100X easier, and much faster, and less boring than a traditional one." The other eight students chose different features as being their favorite, which are probably more reflective of their individual learning needs, with one student noting, "I like that if you don't know a word and it is used but there is no definition you can click or hover over it to get the definition," while six more chose the embedded videos and full-color pictures as being their favorites.

Conclusion

I began this work because I was asked to remove the one resource from my classroom that allowed children to learn through the printed word. Paper textbooks were replaced with a digital resource that was heavy on dynamic content and embedded quizzes, but this change proved to be a challenge when trying to assign reading in a meaningful way. To minimize homework time, I eliminated a guided reading sheet as was past practice and stepped outside of my comfort zone spending considerable time researching and implementing

digital reading strategies - strategies that would encourage my students to read deeply and to extract meaning. Limited to only the CK-12 resource, I learned to manipulate the content to assign small reading passages, and coached my students on the techniques of digital coded highlighting and annotation. Their responses indicate that they saw these digital reading strategies as a benefit over paper textbooks, and their test grades indicate that they are performing at least as well as last year's paper textbook users. As a secondary teacher, I never thought I would have to teach literacy in my classroom, but that is just what I must do in order to encourage students to think for themselves and to draw independent conclusions from data presented to them in order to become the best leaders of tomorrow.

The implications of this four-month research project begin where this project leaves off.   As I went through this project, it became glaringly obvious that if students are going to be scientifically literate in a digital society, secondary teachers are going to need to be trained to teach digital reading strategies (Shanahan and Shanahan, 2008). It is so easy to turn to a video when a student has difficulty reading, but that is exactly the student who needs the reading practice. Instead of taking the easy way, secondary teachers like myself must commit to learning new digital reading strategies (such as highlighting, annotation, text-to-speech, etc…), and consistently teaching and modeling them for the students until they can be as successful through their digital reading as they once were through paper reading. When reading, belief is suspended while integration of knowledge occurs. When watching videos, belief is automatic. We, as teachers, must encourage students to think for themselves and to draw independent conclusions from data presented to them in order for them to become the best leaders of tomorrow. The question that emerges from this research is, how is it best to teach these strategies in a digital age?

About the Author

Lisa Catalano Gizas is in her seventh year teaching Biology and Advanced Placement Biology at West Morris Central High School in Chester, New Jersey. In this role, she is a four-time winner of the annual BASF Science Education Grant. She graduated from the University of Texas at Austin with a BS in Microbiology, and has earned a MS in Biology from Rutgers University and an MEd in Educational Leadership and Instruction from The College of New Jersey. She has previously worked as a research technologist in the fields of cancer research, neuroscience, and immunochemistry. As an adjunct college professor, she taught Microbiology and Human Biology. She would like to thank Charlie, Maria, and Damian for their support of this action research. Email: lgizas@wmrhsd.org.

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EXAMINING THE EFFECT OF LANGUAGE-BASED INSTRUCTIONAL INTERVENTIONS ON ELL AND NON-ELL LANGUAGE PRODUCTION AND TASK-ORIENTED BEHAVIOR IN ELEMENTARY MATH, SCIENCE, AND SOCIAL STUDIES CLASSROOMS

Maggie Hoody

Gold Master Collaborative, InSciEd Out

Joanna Yang Yowler

Mayo Clinic

Michele Link-Valenstein

Gold Master Collaborative

Anna Banti

Gold Master Collaborative

Krystle Eilen

Gold Master Collaborative

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Abstract As the population of K–12 English language learners (ELLs) grows, teachers are challenged to employ strategies that efficiently promote content-learning and language-learning. This paper reports an action research project investigating the effects of three consecutive instructional interventions on student language production at a suburban elementary school. Teachers identified a problem of practice, consulted scholarship for intervention design, and conducted collaborative action research in science, mathematics, and social studies classes. Participants included grades 2–4 ELL and non-ELL students. Data was collected using a modified version of Soto's ELL Shadowing Protocol Form (2012), monitoring frequency of student-speaking, teacher-speaking, student-listening, and on- and off-task behavior. Quantitative analyses found that utilization of message abundancy, 'tasks that require talk,' and stretched language positively impacted student language production and on-task behavior. Statistically significant differences were found in mathematics language production for both ELL (Intervention 1 to 2 $p=0.0028$; Overall $p=0.0023$) and non-ELL students (Intervention 1 to 2 $p<0.0001$) and in task-oriented behavior in science and social studies for non-ELL students (Baseline to Intervention 1 and Overall $p<0.0001$). Differences between ELL and

non-ELL students for both language production and on-task behavior narrowed with time, suggesting that the interventions employed equalized student behaviors.

Introduction

The population of English language learners (ELLs) in public schools is increasing at a rapid rate (U.S. Department of Education, 2017). Statistics vary across the nation, but in Minnesota alone, the number of ELL students has increased 300%—making them the state's fastest growing student population (Minnesota Department of Education, 2016). As a result, educators are challenged to find strategies that promote learning in an increasingly diverse student body.

Integrated Science Education Outreach (InSciEd Out) is one program working within Minnesota to promote educational excellence for all students. It achieves this goal by fostering a culture of change that emphasizes student-driven scientific inquiry and health literacy (Pierret, Sonju, Leicester, Hoody, LaBounty, Frimannsdottir, & Ekker, 2012; Yang, LaBounty, Ekker, & Pierret, 2016). One arm of InSciEd Out, the Gold Master Collaborative, supports teams of teachers as they conduct action research in their classrooms to improve student learning around identified areas for growth. In the fall of 2015, InSciEd Out's teacher partners from City Elementary School (a pseudonym) in Minnesota entered into the Gold Master Collaborative to critically analyze their curricula for reaching all students. The teachers identified a "problem of practice" unique to their school's context to be examined via instructional rounds (City, Elmore, Friarman & Teitel, 2009, p. 102). The problem cited was a culture of low expectations for ELL students that appeared to contribute to a discrepancy in math and science achievement between ELL students and their English-speaking peers (non-ELLs). In particular, teachers noted that ELL students were often "given a pass" when it came to science and math education due to the complexity of academic language unique to these disciplines. Less was expected from ELLs in spoken and written form because the dual demands of learning the language *and* the content seemed too rigorous. Teachers recognized that this "pass" may impede students' proficiency in math and science and sought to interrupt the pattern in ways that could extend to other disciplines and would not be detrimental to non-ELL student learning.

The purpose of this study was to strengthen the instructional core for ELLs (and all students) by increasing student language production. The project addressed the following research questions:

1. How effective are the interventions of message abundancy, tasks that require talk, and stretched language at increasing ELL and Non-ELL language production in mathematics, science, and social studies classes?

2. How effective are these interventions at increasing task-oriented behavior?

Literature Review

Academic Language. Current trends in academic standards have recognized the essential role language plays within teaching and learning. The Common Core Standards for Math and English Language Arts (National Governors Association, 2010) and the Next Generation Science Standards (2013) explicitly address ways in which speaking, listening, reading, and writing impact content learning. Researchers have consequently begun to investigate what these new standards mean for ELLs and the teachers facilitating learning in their classrooms. Many have identified theoretical and practical recommendations (Santos, Darling-Hammond, & Cheuk, 2012; Quinn, Lee, & Valdés, 2012; Lee, Quinn, & Valdés, 2013). Even with the recommendations in place, an analysis of National Assessment of Education Progress data from 2003 to 2013 found the difference between ELL and non-ELL student achievement to be the largest disparity between subgroups of students studied, and one that has increased over time (Carnoy & Garcia, 2017; National Assessment of Educational Progress, 2018). While education policy specifies educators should address the relationship between content- and language-learning in their classrooms, bringing theory to practice remains a challenge. A gap between theory and practice is especially evident in the fields of mathematics and science (Moschkovich, 2012; Santos et al, 2012; Quinn et al, 2012). Careful selection of techniques to highlight the role of language in learning is needed to bridge this gap. Three areas of focus addressed in this study are: message abundancy, language production, and complex tasks. Each was selected because of its established potential for influencing ELLs' reception and production of academic language (Cohen & Latan, 2014; Gibbons, 2015; Hammond & Gibbons, 2005).

Message Abundancy. Message abundancy builds learners' understanding through the deliberate use of multiple modes of communication to convey the same information (Gibbons, 2015). Often, information presented via teacher-talk is delivered at a pace that students, particularly ELLs, find difficult to keep up with. Message abundancy allows a learner to receive comprehensible input multiple ways, thereby increasing the odds that the conceptual or procedural knowledge is, in fact, understood (Hammond & Gibbons, 2005; Krashen, 1982). Use of message abundancy supports students' understanding of language, content, and the symbiotic relationship between language and other forms of meaning that mediate teaching and learning (Hammond & Gibbons, 2005). Resultant meta-awareness equips students with strategies to decode language using other modes of meaning when faced with linguistic uncertainty (Hammond & Gibbons, 2005).

Language Production. In addition to understanding what is being taught, learners need opportunities to produce the language utilized within a teaching and learning session (Gibbons, 2015; Goldenberg, 2013). Swain (2000, 2005) refers to this as comprehensible output. Studies have found that speaking is the foundation of literacy for all learners, advising that ELLs be given opportunities to use extended stretches of language in order to become proficient in reading and writing (Soto, 2012). Historically, the ratio of teacher-talk

to student-talk within teaching and learning sessions has been grossly disproportionate; teachers tend to out-talk students, which can have a direct impact on student learning. Flanders (1970) found that teachers of high-achieving students spend 55% of the time talking, compared with 80% in teachers of low-achieving students. More recent data suggest that there is still much room to increase language production in classrooms. One study found that fifth grade students spend 91.2% of their time in whole group or independent settings (Pianta, Belsky, Houts, & Morrison, 2007). Researchers have yet to develop systematically sound measures of student language production.

Complex Tasks. Embedding opportunities for language production requires thoughtful design of learning tasks. Research has established that well-designed group work affords students more opportunities to interact with speakers, practice language production, and refine meaning, when compared with whole-class discussions (Cohen & Lotan, 2014; Gibbons, 2015). Historically, ELLs have often been subjected to less-rigorous tasks that limit their ability to make content- and language-learning gains (Gibbons, 2015). Lower expectations leave ELLs unable to make the gains necessary to achieve academic equity from a language- and content-learning perspective. This can hold students in a static state of being ELLs (Olsen, 2010). Careful construction of complex tasks that require language production promotes both language- and content-learning (Gibbons, 2015; Hammond, 2008).

Methodology

Setting and Participants. This study utilized collaborative action research by a team of educational professionals and scientists. The action research team consisted of three elementary teachers, one ELL specialist, one Magnet School Coordinator, one educational researcher, and two scientists. The study was conducted in a suburban elementary school located within the Midwest region of the United States. At the time of the study, City Elementary School had approximately 394 students, with 31.3% of the student population identified as ELL. Participants included students from three classrooms: one second grade, one third grade, and one fourth grade (*N* = 53). Both ELLs and non-ELLs were included in the study. Consent was attained via parent-teacher conferences at the beginning of the school year. While *all* students participated in the lessons being studied, only students with signed consent forms were formally observed and included within data analysis.

Instructional Interventions. The project employed three interventional strategies: message abundancy, tasks that require talk, and stretched language. The strategies were selected in an effort to create high-challenge, high-support learning opportunities which previous research established as effective (Gibbons, 2008; Gibbons, 2015; Hammond, 2008; Thomas & Collier, 1999; Walqui, 2007). Additionally, these strategies were chosen because they made learning objectives clear, required students to produce language in vernacular discourse, and challenged students to produce language using discipline-specific academic discourse. The curriculum to which the instructional strategies were applied was the same as that which would have been taught if the project were not taking place. The delivery

method, not the content, was the intervention being studied. Interventions were deployed on a monthly basis.

Message Abundancy. Message abundancy indicates that the concepts and procedures taught during math and science or social studies lessons were presented through at least three forms of modality. During the intervention, input portions of each lesson conveyed meaning through textual, pictorial, gestural, and/or spoken language. Lessons were video-recorded to ensure the strategy was utilized as intended. Math lessons occurred daily, while science and social studies alternated during a shared block. For analyses, science and social studies are grouped to represent equivalent time.

Tasks that Require Talk. Tasks that Require Talk provided opportunities for students to produce oral language during math, science, and social studies classes. The intervention made use of carefully constructed group tasks. The tasks utilized within the intervention were inquiry-oriented and included an information gap that required oral communication between group members. This followed recommendations that a group task should "*require*, not simply *encourage*, talk" and that tasks should be cognitively complex to engage students around the content of focus (Gibbons, 2015, p. 56).

Stretched Language. Stretched language is language beyond students' current linguistic capabilities; it can be specific vocabulary that is unique to subject-area disciplines, but can also refer to the way language is organized, utilized, and valued within a particular academic discipline (Gibbons, 2015; Swain, 2000). For example, scientific discourse values the role evidence plays in substantiating theories or explanations. Without explicit rehearsal of this concept, the value of evidence can be lost when students draw conclusions. Using a 'Give One, Get One' template (Give One Get One, 2018), students were challenged to complete the following sentence frame: "*Our conclusion is _____. The evidence that supports our conclusion is ____."* In this instance of language production, both the academic language and the implicit values of science are strategically scaffolded and rehearsed. Students are stretched beyond simply stating a conclusion to also substantiate that conclusion with a body of evidence.

Data Collection. To measure the interventions' effects on language production and task-oriented behavior, trained observers used a modified version of Soto's (2012) "ELL Shadowing Protocol Form" (p. 119).

Modified ELL Shadowing Protocol. Soto's protocol was designed to follow one ELL student across the arc of an entire school day, monitoring academic speaking, academic listening, and on- or off-task behavior. The modified tool utilized within this study (Appendix A) monitors similar data but allowed ten students to be observed during a single lesson by focusing two observers' attention on an assigned student's behavior at the top of each minute and rotating each observer through a set of five students every five minutes.

Observation Logistics. Students were observed in each classroom at baseline (no interventions) and at the end of each intervention period. A team of two observers was

placed in each classroom to collect data during two separate 30-minute lessons for math and science or social studies classes. During a lesson, each observer monitored five students total. At the top of every minute, the observer recorded details regarding language production, listening, and on- or off-task behavior for the student assigned to him/her for that minute. Observation rosters were carefully constructed such that one ELL and one non-ELL student were observed at the top of each minute. The paired nature of this set-up worked to ensure that variability in response to instruction was not a product of differences in what was happening during the lesson, but rather a product of student response to the same opportunity to learn.

Student Sampling. It is worthwhile to note that there was substantial, but incomplete, overlap between the students observed from intervention to intervention. This is a product of the natural student flow within any classroom environment. Respective sample size numbers are thus provided in each supplementary table to give context to results presented (Appendix B).

Metrics. Each preceding intervention served as the new point of comparison for subsequent interventions (Baseline vs. Intervention 1; Intervention 1 vs. Intervention 2; Intervention 2 vs. Intervention 3), and overall change was also analyzed (Baseline vs. Intervention 3). Language production was analyzed as percent student speaking, which was calculated by dividing the summed observational counts of student speaking by total speaking (student plus teacher). In this manner, percent student speaking can be used as a rough estimate of time spent speaking. On-task behavior was calculated for each student by subtracting observational counts of off-task behavior from five (the total number of observations per student). Total on-task behavior divided by the total number of observations then calculated percent on-task.

Data Analysis. The observational analysis tool used counts of student and/or teacher actions rather than the number of students themselves as a benchmark for data. Unmatched analyses were conducted because total numerical values for student and/or teacher actions were not normalized to a singular possible number. For instance, neither "Student Speaking" nor "Teacher Speaking" could be occurring at the time of each observation (i.e. student is reading, writing, or listening to a video). Statistical tests for categorical data were employed to determine statistical significance of study results. Language production analyses utilized Pearson's Chi-squared, whereas on- or off-task behavior was analyzed by Fisher's Exact Test due to small expected cell counts. Pearson's Chi-squared was also used for initial analysis on the full spread of data to measure potential differences across all time periods (interventions) and ELL/non-ELL students simultaneously. Only one set of observations of each student was included for each intervention for consistency.

Data collected using the observation tool were analyzed in JMP Pro 13 (SAS; Cary, North Carolina). The threshold for significance was $p=0.05$ for the full spread and $p=0.0042$ ($p=0.05/12$) for pairwise comparisons after Bonferroni correction. Four comparisons on each data set looked for differences between ELL and non-ELL students at each intervention level (including baseline). Six additional comparisons probed for changes within both student

cohorts from intervention to intervention. Finally, the two remaining comparisons analyzed changes in both groups from baseline. Any other possible pairwise comparisons were not statistically analyzed and are not reported in any tables or figures. Fisher's results presented are two-tailed *p*-values.

Results

Initial statistical analyses conducted on the full spread of data revealed statistically significant differences in math language production ($p<0.0001$), task-oriented behavior in math ($p=0.0325$), and task-oriented behavior in science and social studies ($p<0.0001$) when comparing pre- and post-interventions. Changes in science and social studies language production ($p=0.1659$) were not significant. Due to significant variation in three of these analyses, pairwise sub-analyses were warranted. Detailed results with exact counts, percentages, and *p*-values are provided in Figure 2.

Language Production. No statistically significant differences were observed in science and social studies language production over time (Figure 1). Non-ELL student speaking percentage remained fairly constant from baseline across all interventions. ELL students' speaking percentage dropped between baseline and the end of Intervention 1 (Baseline: 59.46%; Message Abundancy: 35.14%) but was rescued by the end of intervention 3 (Stretched Language: 54.29%).

In comparison, math language production was lower at baseline and showed more variation across interventions over time (Figure 2). The increase in student speaking percentage from intervention 1 (Message Abundancy) to intervention 2 ('Tasks that Require Talk') was particularly significant for both ELL ($p=0.0028$) and non-ELL ($p<0.0001$) students. In fact, this increase from baseline remained statistically significant for ELL students overall ($p=0.0023$). Gains in math language production elevated students to levels comparable to that observed in science and social studies language production by the end of the study.
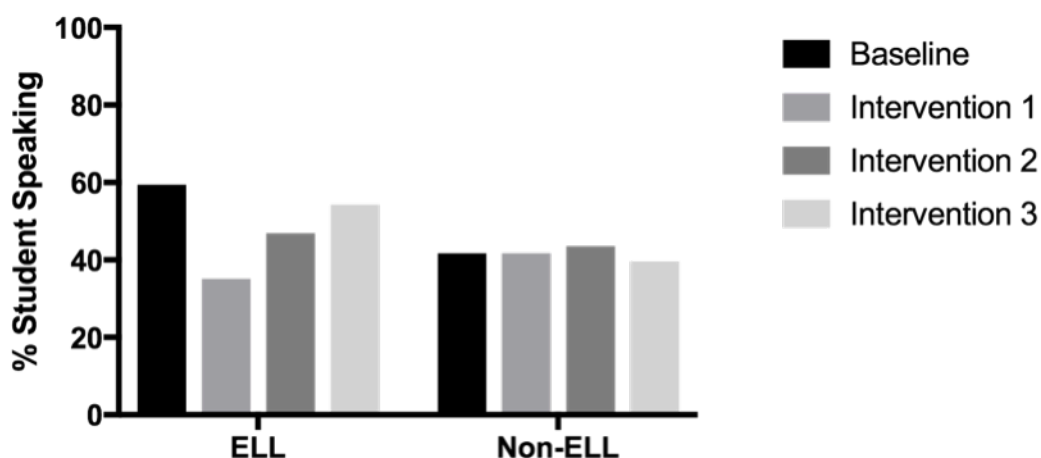
Figure 1: Science / Social Studies Language Production Analysis
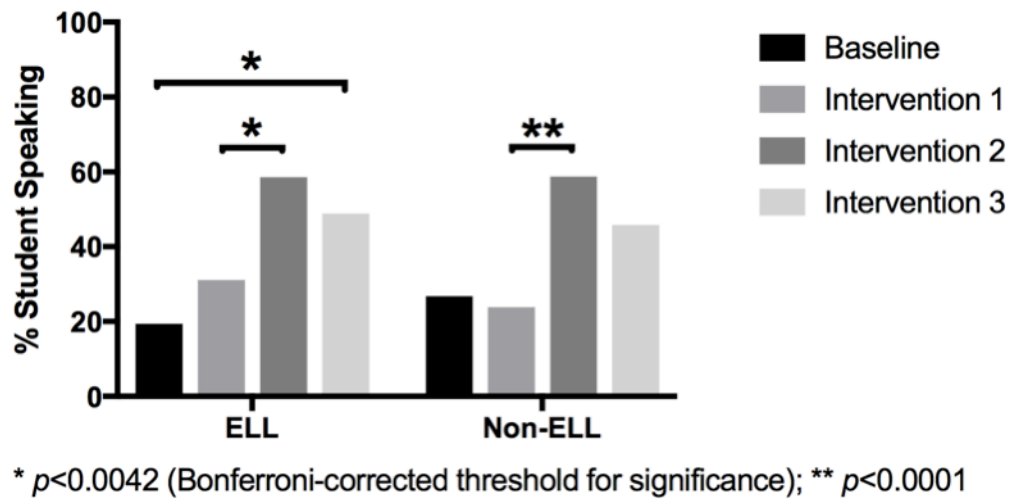
Figure 2: Math Language Production Analysis

Task-Oriented Behavior. On-task behavior in science showed a general upward trend over time (Figure 3). There were no statistically significant differences between ELL and non-ELL students at any given time point across the interventions. Non-ELL students' percent on-task behavior did increase significantly ($p<0.0001$) from baseline to the end of intervention 1 (Message Abundancy). The overall effect of all interventions upon non-ELL students' on-task behavior was also significant ($p<0.0001$).

There were no statistically significant differences in task-oriented behavior in mathematics (see Figure 4). Non-ELL student on-task behavior was much higher at baseline in math (92.86%) than in science and social studies (78.62%) and moderately higher than ELL students' math on-task percentage (84.21%). Percent on-task increased marginally across all interventions for ELL students. Non-ELL student on-task percentage followed a similar pattern for intervention 2 (Tasks that Require Talk) and intervention 3 (Stretched Language).
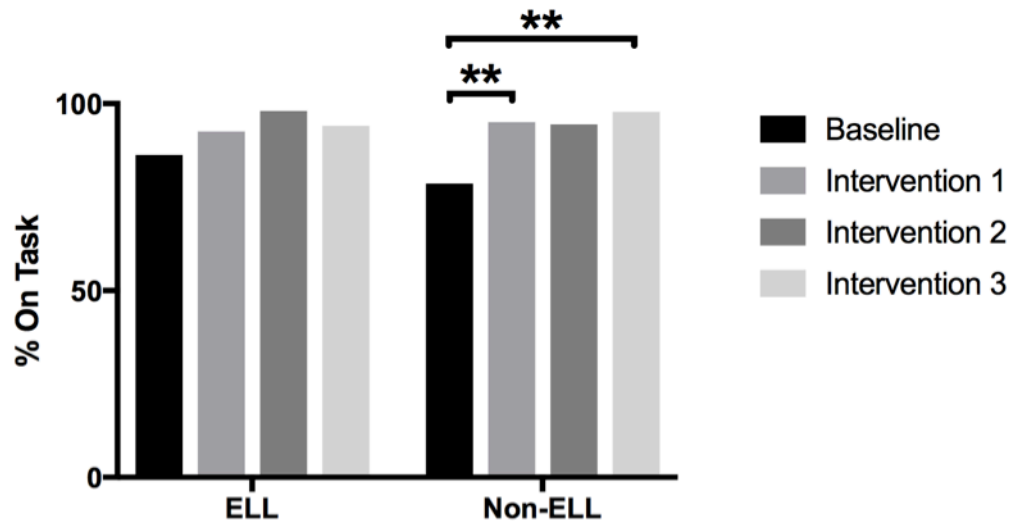
* $p<0.0042$ (Bonferroni-corrected threshold for significance); ** $p<0.0001$

Figure 3: Science / Social Studies On-Task and Off-Task Analysis
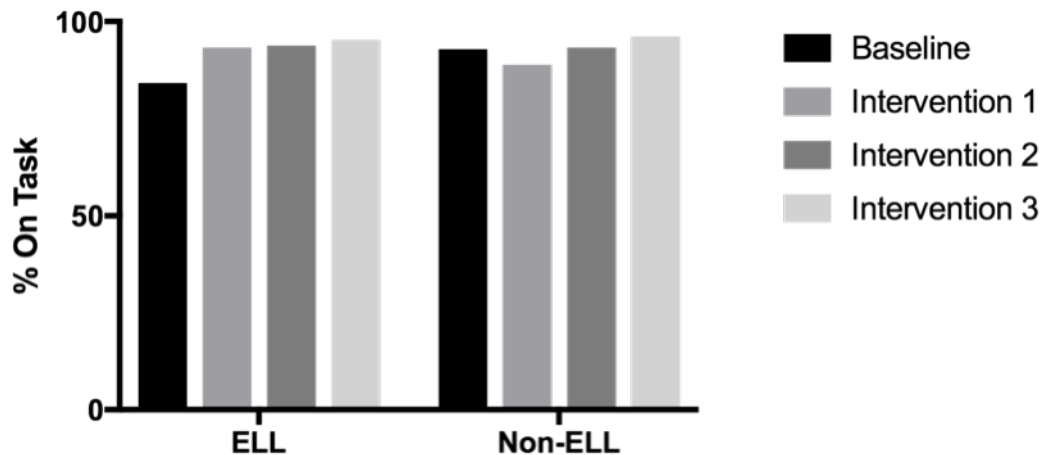
Figure 4: Math On-Task and Off-Task Analysis

Discussion

Language production strategies appear to have had a positive impact overall upon both language production and on-task behaviors for the students in the study. Language production effects are particularly noticeable in math for both ELL (overall $p=0.0023$) and non-ELL students, due in part to a comparably lower baseline in mathematics than in science and social studies. On-task behavior generally trended upward over time, especially for non-ELL students in science and social studies (overall $p<0.0001$), and was high at baseline across the board, particularly for non-ELL students in math (92.86%). Differences between ELL and non-ELL students for both language production and on-task behavior were most pronounced at baseline but narrowed with time, suggesting that the interventions employed equalized student behaviors.

Message Abundancy. Intervention 1 did not appear to be particularly effective for language production, as it greatly reduced ELL student percent speaking in science and social studies (-24.32%) and only had a minor positive effect for ELL students in mathematics. However, the intervention did generally increase on-task behaviors in science and social studies and for ELL students in math (non-ELL science and social studies % on task $p<0.0001$). Teacher perception following intervention 1 predicted these outcomes. All three teachers perceived that the instructional time given to message abundancy took away from time for students to talk. However, they also perceived that the clarity of instruction led to increased and sustained participation by students. As a result, the team worked to refine the manner in which message abundancy was facilitated to make time for more student-talk. Notably, when message abundancy was coupled with 'Tasks that Require Talk', student language production (both ELL and non-ELL) showed a statistically significant increase in math. This suggests that instructional efforts to ensure accessibility of conceptual and procedural knowledge increase the likelihood that students will engage and remain on-task. This has valuable insight to offer general elementary educators and ELL teachers.

Tasks that Require Talk. Intervention 2 made improvements to student language production across the board, partially reversing intervention 1's dip for ELL students in science and social studies and was statistically significantly improving both ELL ($p=0.0028$) and non-ELL ($p<0.0001$) students' percent speaking in math. The intervention also maintained similar levels of on-task student behavior across all groups. Results from this intervention are important because people learn language by using it (Gee, 2008; Halliday, 1993; Vygotsky, 1986). Using language requires both consumption (listening/reading) and production (speaking/writing) (Gibbons, 2015; Krashen, 1982). Tipping talk-time in favor of students necessitates careful attention to the kinds of tasks students are engaged in during teaching and learning sessions. As City et al. state, "The task predicts performance" (2009, p. 30). The tasks that students spend their time engaged in during an instructional session are the best predictor for what students will know and be able to do. Requiring students to listen will build only those skills, but requiring production of discipline-specific discourse will yield students capable of just that. Utilizing tasks that require students to produce language (vernacular and academic alike) throughout the lesson increases students' interaction with both content- and language-learning.

Stretched Language. Intervention 3 had mixed effects upon student language production but generally maintained on-task student behaviors. It continued the trend of reversing intervention 1's ELL science and social studies language production dip but resulted in decreased percent student speaking for other comparisons that were not statistically significant. A possible explanation for the measured decrease in student speaking is incongruity between the observation tool and the protocol of the stretched language task. 'Give One, Get One' prompts were designed to encourage student production of stretched language, both qualitatively and quantitatively. When a student was 'on,' s/he shared a response to each of the sentence frames that comprised the 'Give One, Get One' protocol while the remaining group members listened. The structured nature of the protocol reduced the frequency of dialogic exchange within each small group. The observation tool monitored individual students every fifth minute (i.e. A, B, C, D, E cycle). Given that observations

occurred at the top of every minute and moved to a different student at the end of each minute, it is possible more student-talk took place than was captured by the observation tool.

Summary. While quiet classrooms were once considered ideal for the facilitation of learning, awareness that language production is correlated with high student achievement (Flanders, 1970) challenges educators to promote student-talk throughout teaching and learning sessions and especially within complex, interactive tasks. Relegating student-talk to whole group discussion at the beginning or end of a lesson unnecessarily limits the number of students who have the opportunity to practice language production. The largest gains in language production over the course of our study were found post-intervention 2, 'Tasks that Require Talk'. This particular intervention specifically challenged more students to produce language, as it required oral communication by design. From an equity perspective, it may be an effective tool for ensuring equal access to language production, which may be the most efficient opportunity to learn.

That said, evidence in the field suggests the kind of talk students engage in matters (Gibbons, 2015; Huang, Normandia & Greeg, 2005; Schleppegrell, 2004; Soto, 2012). Language production alone does not equate itself with the acquisition of academic discourse. There will always be a need to model the unique style of language that accompanies any academic discipline. Yet, modeling alone is not sufficient. Students need to "talk their way into habits of expressing higher-level knowledge structures" (Huang et al., 2005, p. 44). Tasks that require talk can theoretically benefit from being coupled with stretched language, though 'Give One, Get One' did not appear to be the most ideal protocol for the student population here, however.

Finally, using a tool to monitor student language production provides a more accurate read of exactly how much language students are producing within a typical lesson. Too often, quantification of student-talk is left to teacher perception. Using a modified version of Soto's (2012) ELL Shadowing Tool Form enabled us to have a more objective measure of the amount of student-talk relative to the amount of teacher-talk. This strategy could be utilized in classrooms on a routine basis, and the data could be utilized to inform (re)design of future instruction.

Implications and Conclusion

The goal of this research was to identify ways to strengthen the instructional core in a manner that promoted student language production. In particular, the action research team worked to narrow a perceived expectation gap between ELL and non-ELL students with regard to language production. Interestingly, baseline data did not support the perceived expectation gap.

The study found that systematic use of interventional strategies had a generally positive impact on ELL and non-ELL students' language production and task-oriented behavior. This is significant because stakeholders in school communities sometimes worry that use of strategies to promote learning for ELL students will diminish the learning of non-ELL

students. We found the opposite effect. Systematic use of strategies recommended for ELL students had a largely positive impact on language production for both ELL and non-ELL students. Additionally, the study found that systematic use of the strategies of focus resulted in increased or maintained on-task behavior during mathematics, science, and social studies classes.

Limitations. The study was limited by the variability that accompanies all elementary education settings. Teachers, students, and para-professionals differ from classroom to classroom. This inconsistency constrains the goal of having the independent variable be the only difference between the experimental group and the control group. Other school- and/or district-based initiatives also ran concurrent to the interventions being studied. The findings must therefore be read through a lens that recognizes other modulating factors.

Secondly, this study used a proxy for measuring student-talk time and on-task behavior, as it did not continuously monitor students and instead observed each student at five specific time points during one selected class period. This was the result of the observational tool utilized, as well as practicality in a classroom setting. More exact measures of time spent talking or time spent on-task could be obtained by using a stopwatch. More class periods could also have been observed to ensure that the data taken was not as heavily influenced by the lesson being delivered on any particular day.

Finally, this study did not work to establish a direct correlation between student language production and academic achievement, which previous studies have done (Flanders, 1970). The study conducted cut across three grade levels: second, third and fourth. Assessment policy within the district placed limits on the amount of standardized testing each student could complete. The requirements resulted in different testing schedules across grade levels. As such, a statistical analysis of student achievement as measured by a single, growth-based assessment could not be completed for this particular population.

Recommendations. Recommendations that evolve out the study fall into two categories: future research and curriculum development.

Research:

- *Quality of student-talk:* If a student-based recording device is used, researchers could analyze student-talk to measure qualitative shifts from vernacular language to academic discourse.

- *Quantity of student-talk:* If a student-based recording device is used, researchers could analyze student-talk to determine exact amount (vs. frequency) of student language production during each lesson.

- *Correlation to student-achievement:* This study did not establish a correlation between language production and student achievement. A similar study could be conducted that focuses on students at a single grade level such that a common

assessment could be utilized to investigate the impact of language production on student achievement.

Curriculum Development:

- *Mathematical Tasks that Require Talk:* Well-designed math tasks that utilize group-work and require talk increased student language production in this study but are rarely found in teaching and learning resources. Establishing a library of "tasks that require talk" for students at each grade level would be useful to teachers.

- *Code-Switching:* A step this study did not take was to systematically invite students to explain new concepts in their own language first. Research has shown this to be an effective approach (Brown & Ryoo, 2008).

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Appendix A: Data Collection Tool

Modified from ELL Shadowing Protocol Form (Soto, 2012, p. 119)

Time	Student	Specific Activity or Location	Academic Speaking	Academic Listening	If student is *not* listening	Comments
0	A		o S to S o S to T o S to small group o S to whole class o T to S o T to small group o T to whole class	One or two way, mostly to… o student o teacher o small group o whole class o video o ipad	o Reading or writing silently o Student is off-task	
1	B		o S to S o S to T o S to small group o S to whole class o T to S o T to small group o T to whole class	One or two way, mostly to… o student o teacher o small group o whole class o video o ipad	o Reading or writing silently o Student is off-task	
2	C		o S to S o S to T o S to small group o S to whole class o T to S o T to small group o T to whole class	One or two way, mostly to… o student o teacher o small group o whole class o video o ipad	o Reading or writing silently o Student is off-task	
3	D		o S to S o S to T o S to small group o S to whole class o T to S o T to small group o T to whole class	One or two way, mostly to… o student o teacher o small group o whole class o video o ipad	o Reading or writing silently o Student is off-task	
4	E		o S to S o S to T o S to small group o S to whole class o T to S o T to small group o T to whole class	One or two way, mostly to… o student o teacher o small group o whole class o video o ipad	o Reading or writing silently o Student is off-task	

Teacher: _____   Date: _____   Time: _____ Subject: _____   Observer: _____

Appendix B: Supplementary Tables

This appendix contextualizes figures presented in the main text. The tables include sample sizes, exact counts, and percentages for data graphed in Figures 1 through 4. Full *p*-values are also provided with bars connecting each pairwise comparison run. Significant *p*-values (after Bonferroni correction) are asterisked in all tables.

Supplementary Table 1: Science / Social Studies Language Production

	N	SS	TS	% SS
ELL 0	19	44	30	59.46%
Non-ELL 0	29	40	56	41.67%
ELL 1	16	13	24	35.14%
Non-ELL 1	28	30	42	41.67%
ELL 2	10	15	17	46.88%
Non-ELL 2	18	27	35	43.55%
ELL 3	10	19	16	54.29%
Non-ELL 3	18	23	35	39.66%

X^2 p-value pairwise comparisons:
- 0.0214, 0.0156, 0.6096
- 1.0000, 0.8057
- 0.5088, 0.3220
- 0.8261
- 0.7585, 0.5445
- 0.6655
- 0.1696

Supplementary Table 2: Math Language Production

	N	SS	TS	% SS
ELL 0	19	12	50	19.35%
Non-ELL 0	28	24	66	26.67%
ELL 1	18	18	40	31.03%
Non-ELL 1	27	20	64	23.81%
ELL 2	16	34	24	58.62%
Non-ELL 2	27	60	42	58.82%
ELL 3	17	20	21	48.78%
Non-ELL 3	26	33	39	45.83%

X^2 p-value pairwise comparisons:
- 0.3362, 0.1478, 0.0023*
- 0.7285, 0.0133
- 0.3436, 0.0028*
- <0.0001*
- 1.0000, 0.4133
- 0.1226
- 0.8453

Supplementary Table 3: Science / Social Studies Task-Oriented Behavior

	N	Off	On	% On
ELL 0	19	13	82	86.32%
Non-ELL 0	29	31	114	78.62%
ELL 1	16	6	74	92.50%
Non-ELL 1	28	7	133	95.00%
ELL 2	10	1	49	98.00%
Non-ELL 2	18	5	85	94.44%
ELL 3	10	3	47	94.00%
Non-ELL 3	18	2	88	97.78%

Fisher's p-value

0.1721
0.2280
<0.0001*
0.2638
0.5542
0.2487
1.0000
<0.0001*
0.4209
0.6173
0.4438
0.3485

Supplementary Table 4: Math Task-Oriented Behavior

	N	Off	On	% On
ELL 0	19	15	80	84.21%
Non-ELL 0	28	10	130	92.86%
ELL 1	18	6	84	93.33%
Non-ELL 1	27	15	120	88.89%
ELL 2	16	5	75	93.75%
Non-ELL 2	27	9	126	93.33%
ELL 3	17	4	81	95.29%
Non-ELL 3	26	5	125	96.15%

Fisher's p-value

0.0508
0.0639
0.2972
0.0266
0.3509
1.0000
0.2931
0.2848
1.0000
0.7407
0.4124
0.7420

MATHEMATICS STATIONS IN A THIRD GRADE CLASSROOM: ARE THEY WORTH IT?

Rachel Perry

Abilene Christian University

Abstract Mathematics stations allow for students to complete tasks individually and in small groups using a variety of manipulatives, games, and technology to practice the same mathematical content. The purpose of this study was to gain a deeper understanding of teacher and student perceptions of the use of mathematics stations in a third grade classroom, and how mathematics stations shaped student feeling toward mathematics. The author collected data through student survey, teacher and student interviews, observations, and a personal research journal. After analyzing the data by using the constant comparative method the author found four major themes. These themes included evidence of student engagement perceived by the teacher and students, peer conflicts that act as barriers, meeting student needs, and finally, the teacher perceptions of behavior management during stations. This study may provide useful information to other educators who are deciding if they would like to implement mathematics stations into their classroom.

Introduction

The researcher and the classroom teacher simultaneously laughed and shook their heads as they both reflected on the journey it had been implementing mathematics stations into the classroom for the first time this year. During mathematics stations, it is common to see small groupings of students spread around the classroom, whether that is lying on a large carpet, sitting on pillows, working at desks, or even standing with clipboards all working on tasks of mathematical content. There is a hum of problem solving, questions being asked, laughter, and possibly loud voices coming from the mathematics game small group. The researcher asked Mrs. Oliver (all names are pseudonyms), the third-grade teacher, "What would you say is the best part about implementing math stations into your classroom this year and why?" This was her response:

"Well, I am going to sound like a broken record, but really just the students' engagement, the students' *want* to do the stations, to learn. In stations, they are learning, and if they want to do math stations, then they are wanting to learn, even if they don't quite understand that, or know that this is fun, this is a game, but that they are learning. And I am

like, 'yeah, we can play a game all day long if you are learning.' So, I think that has been the best thing, watching them take ownership of their own learning, and watching them problem solve between each other, and … I watched them figure it out together, and something that I think stations has brought out in them. I would say that is the best part."

Purpose. Mathematics can often be a subject that is daunting for teachers to teach because of personal or students' feelings of anxiety towards the subject. As a way to change these negative associations with the subject, mathematics stations are a different way students can learn while interacting with their peers and hands-on materials. Mathematics stations are areas set up around a classroom where students can practice the same mathematical content, but in a variety of ways. With various manipulatives and opportunities to use different learning styles, students rotate through the stations in groups of their peers to practice their learning (Diller, 2011). During this study, I was a graduate student completing a one-year clinical teaching placement in a third-grade classroom at Seaside Elementary (all location names are pseudonyms). Seaside was a Title I school that served a diverse population of approximately 450 students in grades K-5 on the east side of Clarence Independent School District home to around 122,000 people. The student body of Seaside Elementary is represented by 31.5% African Americans, 38.7% Hispanic, 25.9% White, 1.2% Asian, 0.2% Pacific Islander and 2.5% two or more races. Eighty-four percent of the Seaside Elementary population is economically disadvantaged, 18.5% are English Language Learners, and 5.9% are considered special education. The school has a mobility rate of 24.4%.

My cooperating teacher used mathematics stations for the first time this year, and I wanted to know if after all of the time, work, and set-up, are mathematics stations a method that students and teachers enjoy? Since there was not a lot of research about the student and teacher perceptions of math stations in elementary classrooms, the results of this study may impact the way teachers go about using mathematics stations in their classrooms.

My research questions included:

- What are teacher and student perceptions of the use of mathematics stations in a third grade classroom?
- How do mathematics stations shape student feelings towards mathematics?

Literature Review

In a mathematical setting, the use of multiple stations can focus on the same curriculum content goal by using different manipulatives, activities, games, or technology (Van de Walle, 2016). Students can complete the task within the station independently of the teacher, while working with a variety of materials either independently or within a small group (King-Sears, 2007). There must be explicit instruction of the mathematical concept along with clear expectations for station time before the students are released to rotate through the stations as a form of guided or independent practice (Van de Walle, 2016). Stations, "benefit students and teachers by maximizing instructional opportunities through

simultaneously providing varied tasks and activities for students with diverse learning needs to practice what they have learned" (King-Sears, 2007, p. 147). Tasks in stations often include activities that resemble playing when compared to an independent worksheet assignment. Wing (1995) found that if students can complete an activity that is more play-like, then it might allow for the student to feel more ownership over the task than they might have felt with a more work-like task. While students know the difference between work and play, simulating tasks that can merge the two together in a work-play scenario, lends itself to a greater degree of pleasure (Wing, 1995). If this need for a more play-like structure is greater for one student over another, teachers can benefit those students by catering their instruction that is the best fit for them.

Teachers have the ability to differentiate instruction to meet the needs of their students within the mathematics stations. This differentiation can be through the design of the tasks in each station as well as the organization of small groups within the workshop model. In her research, Ashley (2016) described creating differentiation by assessing what the students already know and then deciding how to provide instruction that will meet each of their needs. Combining student academic needs, their learning styles, and how they show their understanding, all play a part in the differentiation in mathematics stations (Andreasen, 2012). Stations could look like a teacher table where students get additional help with a specific part of the lesson or enrichment on the topic based on their need. Other stations could include the use of manipulatives with pencil to paper problems, and a computerized game with audio and visual practice, or hands-on games with peers (Andreasen, 2012).

Specifically chosen small groups are used by teachers during mathematics stations to organize their students based on mathematical instructional need. Benders and Craft (2016) explained in their study that the flexibility a teacher has in creating small groups allows for changes to be made when students' academic needs improve or require more attention. Through their study, they saw that the use of small groups allowed for attention to be paid, "to the students having difficulty with just one skill or concept, to those who are advancing quickly through the material and need new challenges" (p.7). Benders and Craft (2016) suggested that heterogeneous grouping allows for peer support and learning from one another. Ding, Li, Piccolo, and Kulm's (2007) study showed that teachers should allow for interactions and teaching between peers to occur and encourage their students to use their peers as resources. There has to be a balance between allowing students to struggle while solving a mathematical problem either independently, or in a small group before the teacher steps in and redirects (Ding et. al, 2007). For those students having more difficulty with the mathematical content, there is often mathematics anxiety involved. In Harari's (2013) exploratory study of mathematics anxiety, two thirds of adults stated that they have negative associations with mathematics. From a tough concept to a mean teacher, mathematics anxiety can begin as early as the primary elementary grades (Harari, 2013). When students are working within homogenous grouping, Merritt's (2017) findings suggest the students' mathematics skills, confidence and attitudes improve. Teachers can intentionally match students with greater needs, whether academic, social, or emotional.

The results of the previous studies suggested that the use of the mathematics stations model may be helpful in encouraging a work-play mindset while interacting with mathematical content in various ways. Increasing differentiation of instruction can help meet the individual needs of students through small group pairing and peer collaborations. While the research has shown success in the use of mathematics stations, this study will give insight into student and teacher perceptions and feeling towards the use of mathematics stations when practicing mathematical content. This research is unique because very few studies have been conducted on understanding if students and teachers enjoy using stations as a tool for practicing mathematics. Greater knowledge on student and teacher perceptions of mathematics stations can help inform educators on why or why not to use mathematics stations in their classroom.

Methodology

Within the third-grade classroom where I was clinical teaching, I conducted my action research study on student and teacher perceptions and feelings towards the use of mathematics stations as a way to practice mathematical content. During the study, I was both a teacher and a researcher, so the students were comfortable with my role as both.

Participant Selection. There were 19 students total in the third-grade class where I was doing my clinical teaching. There were seven females and 12 males who varied in ethnicities and academic abilities. Since the entire class rotates through the stations, I wanted to have all 19 students (if applicable) respond to the surveys and be eligible to be observed. There were 11 students who returned their signed forms to be able to participate in the research study. After my cooperating teacher signed the consent form, I interviewed her on her perceptions and feelings of the use of mathematics stations in our classroom.

I choose a sample of students that represented the makeup of our class for the interviews. This method of intentionally selecting interviewees is described by Patton (1990) as purposive sampling, which is a method of selecting participants who will best contribute to the achievement of the research objectives. The answers to the surveys informed who was selected for the student interviews; specifically, I looked for six students who would give the most information in their interview answers.

Data Collection. One survey was given to each participant. As a form of inquiry data, the survey asked about the students' perceptions of the mathematics stations, and how the students felt about using mathematics stations to practice mathematical content. More than half of the class was reading below grade level when I began designing this research study, so I believed that the students would be able to give me the most information if they could answer the survey questions by using a Likert scale (see Appendix A). I added two open-ended questions to the end of the survey, and I gave them the option to answer the question at their writing ability level. Since mathematics stations had been introduced in the fall semester, I gave the surveys at the beginning of my research in the spring semester

because the students already had time to form opinions and feelings towards the use of mathematics stations from the previous semester. The surveys were given in the beginning of my study so that I could use them to inform my decision of which students I would interview.

I conducted one, 30-minute, semi-structured interview (Hendricks, 2017) with my cooperating teacher (see Appendix B). I had the freedom to ask the teacher to expand on her answers or asked additional questions that naturally came up from our conversation. Since my cooperating teacher had previously decided to try using mathematics stations this year, and then had a full semester of using them, the interview occurred during the beginning of my study.

After reviewing the survey results, I choose six students for one (10-15 minute) semi-structured interview each to give me a better representation of the class, and to be prepared if someone moved or could not participate in the study (see Appendix C). I looked for six students who gave me the most information in their answers regarding their perceptions and feelings towards the use of mathematics stations. I interviewed two students whose perceptions and feelings showed they liked the stations, two who felt ambivalent, and two who disliked the mathematics stations. These interviews were semi-structured (Hendricks, 2017) as I asked the students to expand on their answers given in their survey in addition to planned interview questions.

In addition to survey and interview data, I observed the mathematics station rotations for three days a week for two weeks so that I saw a complete rotation of the stations twice. In the second week, I saw the students interact with new content and materials that differed from the first week. There were two 13-minute rotations of mathematics stations a day, with six stations to visit, each group would rotate through all six stations after three days. It was important for me to see each group go to each station because of the variation of academic levels within each small group. I continued to interact with the students and hosted my own small group station during the rotations. Because I wanted to continue with my normal interactions with students, I conducted head notes (Hendricks, 2017) during the observations and then made more detailed notes after school that same day. I observed the students' conversations, engagement, use of the materials, etc. while in the stations.

I wanted to keep a research journal while conducting this research because I was curious of whether I would want to use mathematics stations in my future classroom. Through my personal journal notes, I believed that my perspective of the use of mathematics stations would offer a unique side to the data as a clinical teacher using mathematics stations for an entire year in a third-grade classroom. I reflected later in the evening on the six days that I observed the mathematics stations.

Data Analysis. The constant comparative method (Hubbard & Power, 2003) was used to analyze the data collected, which includes the coding of patterns and themes that I categorized. After coding, I analyzed about twenty percent of the data, and then I used those codes to code each of the surveys, interviews, observations, and the research journal from my study. Approximately 15 level I codes emerged from my data. These codes show what is on the surface of the data; they are basic actions within the data and require little analysis of the data to understand (Tracy, 2013). Once I discovered that a code had repeated itself multiple times throughout the data, I created level II codes. These codes require analysis and explanations of patterns within the data, and I organized my data based on the major themes that arose (Tracy, 2013). I had four level II codes, and I wrote memos describing them, which aided me in understanding their meanings and connections to the other data I had collected (Tracy, 2013). These codes were created into a codebook (see Table 1) that listed each code, definition and an example.

Table 1: Explanation of Codes

Code Name	Level	Definition	Example
Positive peer relationships	I	Any instance of students were working well together	"I like working with my group of three because they are all my friends and they are funny!"
No independent practice	I	Student's request to not have to go to the independent practice station and complete the independent task	R- "...you said if you could add or change anything it would be independent practice..." K- "NO independent practice!"
Peer Conflict	II	Negative interactions between students within the class	"I don't like my group at all! I just want to get out of there" "We don't get along that good..."
Student engagement	II	Favorable student beliefs or impressions of math stations	R- "Excited! Why are you excited during math stations?" M- "Cause during the whole day, it is the thing I really want to go to." R- "So if we told you, 'no math stations, never again! What would you say?" S-"Mmm I would say, 'dang I love math stations."
Student engagement	II	Any instance students are focused on their task at hand	"I want to say engaging... I see my students engaged when they are doing it, I will watch them, and I am like they are having too much fun over there, but then it's with the game..."
Pacing	I	Amount of time spent during each rotation of station or amount of time spent on specific content	"And now we have gotten to the point where we can do two, 15 minute stations because this doesn't take us as long to

			transitions, students know what to do, where to go, how to use the materials…"
Positive teacher perceptions	I	Favorable teacher beliefs or impressions of math stations	"I just see them all engaged, so I have gone from feeling frustrated to finding something that works, to wanting to get to all three stations, to wanting to get to make sure that we have time for stations just because of the joy that it brings!"
Problem solving skills	I	Students exhibiting actions towards figuring out an academic or social problem	"I think allowing them that time to talk and problem solve in their stations, I see them...wanting to talk about things on the carpet during a whole group lesson, and wanting to figure things out."
Meeting student needs	II	Able to provide instruction and materials that can assist the student at their academic level and their pace	"…I'm doing everything I can to reach them where they are at, and I have seen a lot of progress…"
Flexible grouping	I	Students are organized in small groups based on academic level or social needs	"I kind of just based it off of formative assessment, what I noticed what the students were understanding, what they weren't understanding… from that data we collected I created my groups, and the groups are flexible, like I can move them whenever."
Behavior management	II	Teacher actions towards class control or setting expectations	Mrs. Oliver gave a warning to the small group at the math game station saying that all students need to be sitting up (instead of lying down or sitting in a comfy chair) and they need to be playing the game. Students adjusted accordingly.
Differentiation	I	The way the teacher plans and responds to students' needs	"... like when I know that they are struggling, I can find different ways to teach it…"
Teacher-student relationships	I	Any instance of positive teacher and student interactions	"…like I am able to help them… I think they know that. I think they see that we want to help them... I have seen a lot of difference in their attitudes, um, you know, by building that relationship, like not only teacher to student, you know like that trusting, caring relationship, but really academics like I want to help you with this…"

Leader in Me	I	School-wide program that teaches leadership and life skills to students and creates culture of empowerment. The 7 Habits are principles in which the program stands	Mrs. Oliver- "…watching them take ownership of their own learning and watching them problem solve between each other, and figuring something out, like you know, I, we are a Leader in Me school and I found myself on Tuesday saying, okay go think Win-Win, you and your partner working together, I am not doing it, and I watched them figure it out together…"
Flexibility	I	The ability to change content, time frames, or groups at any time during stations	S-"…you can use one Habit and then um it would be easy to resolve it…" "Yeah, yeah I mean and sometimes it is very flexible, like I have something planned, I have a worksheet or I have this, and then they, or something comes up in our conversation, on the first problem and I am like oh we are not ready, we need to backup and then I can change it on the spot."
Outside support & resources	I	Materials used and colleague or administrative support for the classroom teacher	"finding someone who is an expert on it, and then looking through materials, and books, I mean I googled things… just being able to talk to people on how to make it better was just really the most important thing for me to like keep that persistence…"
Doesn't like Fast Math	I	Students' opinion of a technology-based math program that tests their fact fluency.	C-"On Fast Math they have to do a typing challenge, and it gets really annoying" R- "So how would you describe your mood during math stations…" W- "Mad, on Fast Math."
Prodigy!	I	A technology-based math program that students speak positively of. They complete mathematical questions in between adventures in a virtual world	S- "Technology (station), I like technology the most" R- "…what is the other game you get to play?" S- "Prodigy!" R- "So if you had to pick between Prodigy and Fast Math which one would you pick?

			C- "Prodigy, definitely."
Negative student perceptions	I	Opposing student beliefs or impressions of math stations	R- "...so if we told you that we are not doing math stations anymore… K- "WOOOHOOOO (laughs) I would be so happy! Cause I don't want to do math stations."
Setting expectations	I	Teacher setting up what the students can and cannot do during math stations	...there was a very strict conversation about respect and expectations. With that, she said that if there is any off-task behavior or a teacher has to correct behavior during stations, then the student will just go back and sit at their desk. That was their warning and then she released them into their stations. The students moved quickly and began setting up their activity or area.

Results and Discussion

As themes and patterns within the data came to the surface, I organized the findings into four level II codes: student engagement, peer conflict, meeting student needs, and behavior management. Within each of the following sections, I unpack the evidence from the student surveys, both teacher and student interviews, and observations and my personal research journal that relates to these level II codes.

Student Engagement. Right from the beginning of collecting data I saw that students were engaged in mathematics stations. This code stemmed from the evidence that students were focused on their tasks, wanted to participate in mathematics stations daily, and were completing what was assigned to them. The student surveys were my first data point, and 73% of students who completed the survey said that they felt very happy or a little happy about learning mathematics through mathematics stations. Similarly, 82% of students said that they either felt very happy or a little happy about going to mathematics stations each day (see Table 2). From the information in the surveys, I was able to interview six students about their perceptions and feelings towards mathematics stations and how mathematics stations shape their feelings towards mathematics. The students discussed with me different games, skills or mathematics activities that they enjoyed and learned from during stations whether they said, "I learned this specific mathematical concept" or not. Station activities included similar ideas to those outlined by Van de Walle (2016) such as using different, engaging manipulatives, activities, games, or technology as students rotate through the stations as a form of guided or independent practice. In his interview, a student named Spencer mentioned that the material he got to learn and practice during mathematics stations helped him later on in the week when there was a quiz. More

specifically, he stated that in the fact fluency station he got to practice his multiplication flash cards, and he saw how that helped him during his "sixes" quiz they had the previous Friday. Another student, Key Key said that during mathematics stations, "you are still learning stuff, and you are having fun as well!"

Table 2: Survey Analysis

	Very Happy	A Little Happy	A Little Upset	Very Upset
1	64%	9%	18%	9%
2	64%	18%	18%	0%
3	36%	27%	36%	0%
4	27%	9%	18%	45%
5	45%	0%	18%	36%
6	27%	0%	27%	45%
7	36%	9%	18%	36%
8	55%	0%	36%	9%

In addition to student feedback, Mrs. Oliver recalled multiple times when students made comments about liking mathematics stations. She had seen that they seemed to be doing good work in their stations, which seemed to be motivating to her students. Mrs. Oliver spoke about moments where she had heard specific conversations about mathematical content or saw what seemed like off task behavior or having too much fun. She quickly realized that the students were just playing the game, or that they suddenly understood the material better and then excitement arose from that. Wing (1995) found that when students were engrossed in play-like activities, then it gives the illusion of more play than learning while the result is quite the opposite. While the students feel like they are playing during mathematics stations, their level of learning and engagement increases. Mrs. Oliver said that sometimes the students were so engrossed by the game aspect of the station activity that they did not even realize that they were learning; she said, "Yeah we can play a game all day long if you are learning!" She had seen the students wanting to talk and problem solve in their stations and that they appreciated the time to talk through their mathematical problems with their peers. Mrs. Oliver said she had seen greater engagement arise within the whole group lessons once the students had interacted with that same content during math stations the previous day.

Based on the students' engagement in tasks during mathematics stations, their desire to go to mathematics stations daily, and the teacher's evidence of their engagement, I would say that most students had positive perceptions of the use of mathematics stations in their class. Mrs. Oliver recalled that if there was a changeup in the schedule where mathematics stations could not be completed that day, the students asked, "Well, are we going to do math stations? Why aren't we doing stations?" Ultimately, the students were learning in every station that they went to, and sometimes they did not even realize it. They might not have told me, "Hey I love math now," but I saw in this study that students were laughing and socializing and producing answers to mathematical problems while they were in stations, and so their engagement helped shape their feelings towards mathematics.

Peer Conflict. Peer conflict began as a level I code and then quickly became a prominent level II code because of the 14 times that I coded peer conflicts within the data. I defined peer conflict as an instance when there were negative interactions between students within the class - when students were not getting along, not synergizing, or working well with one another. One of the open-ended questions from the student survey asked the students to tell me about how they felt about working with their peers during mathematics stations. During the time that the survey was given and the first week of my observations of mathematics stations, Key Key and Spencer were in a small group together for stations. Based on their survey responses, I asked them to expand on their specific feelings and experiences with their peers during mathematics stations. The biggest conclusion from those two interviews was that the students would have liked to change who was in their small groups since they had been in the same groups for quite some time.

When I asked two other students about their peer interactions or experiences, Chester said when in a group of four there is more to talk about, which usually resulted in more drama. He said that when their group was not synergizing together, then he would say that his group was his least favorite part about mathematics stations. Warren said that he would have liked to work in partners instead of groups of four because people argue a lot when in a bigger group. When I asked Mrs. Oliver about the size of the groups, she suggested that the ideal group is actually just partners when she stated, "Groups of four is just too many… behavior gets in the way of their learning… two people working together is manageable." The biggest barrier to having partners for stations was that there is not enough space or supplies for multiple groups to be doing the same task at the same time, so groups of three or four worked for us, at the time.

Five out of the six students that I interviewed mentioned something about peer conflicts during mathematics stations, whether it was something they personally encountered or that they had seen from other groups. In a combination of the student interviews, week one's observations and experiencing some of the poor relationships, Mrs. Oliver and I saw that there was a problem with peer conflict that we needed to address. In between my first and second week of my observations, Mrs. Oliver and I decided that it was necessary that we switch around some of our small groups. Ding, Li, Piccolo, and Kulm's (2007) study showed that teachers should allow for interactions between peers to occur, however there has to be

a balance between allowing students to struggle while solving a mathematical problem before the teacher steps in and redirects. We found, however, in our classroom, that the times that we needed to step in the most were for social issues instead of a lack of understanding of a mathematical concept. In the second week of my observations, I saw fewer instances of peer conflicts once the small groups were changed.

Peer conflicts allowed for more negative student perceptions of math stations. If they were distracted by a peer in their small group or sometimes from another disruptive group, then that was taking away from their learning during mathematics stations. I could see how the social aspect of mathematics stations could create negative feelings towards mathematics. Due to the social and relational aspects of mathematics stations, students could very easily associate negative social experiences with negative mathematical experiences. On the other hand, while students were having conflicts between their peers, they were also learning and using problem solving skills that might not have other opportunities to be used within the classroom. While peer conflict was evident within our model, it was not always a negative addition to mathematics stations.

Meeting Student Needs. From the intentional grouping of the students, to the teacher-student interactions, meeting student needs was evident throughout our model of mathematics stations. Mrs. Oliver mentioned multiple times about the advantage she had when getting to know her students on a more personal level and at a quicker pace because of the model of stations. At the beginning of the year, it was hard to know right away the needs of each learner and what they did and did not know. With the small groups visiting the teacher station more than once a week, Mrs. Oliver said that they could not hide if they were struggling. She was able to directly see their misconceptions or even what was no longer challenging for the students, and then she could adjust accordingly. With the flexibility of mathematics stations, Mrs. Oliver and I were able to go back and reteach a concept, dive deeper into a student's question, or offer higher order thinking depending on the small groups' needs on that day during that station.

Since the students were typically grouped at similar academic levels, the small group and teacher were able to problem solve together through the differentiation Mrs. Oliver was able to offer her students. Andreasen (2012) stated that while creating differentiation, student academic needs, their learning styles, and how they show their understanding, are all necessary to consider in their grouping. Mrs. Oliver mentioned that often, teachers have to move on after multiple lessons within whole group settings. If a student does not understand, those issues might not be addressed right away, but since our stations followed the whole group lesson, Mrs. Oliver was, "able to slow down and build the foundation with them before piling other things on them." Benders and Craft (2016) also saw in their study that the use of small groups allowed for attention to be paid, "to the students having difficulty with just one skill or concept, to those who are advancing quickly through the material and need new challenges" (p.7). They exercised their flexibility in making changes to their small groups based on their student's needs (Benders and Craft, 2016).

There were two specific times during observations where I saw differentiation and flexibility based on what the student needed. One student had recently failed an assignment, so at her table for stations, Mrs. Oliver was able to go back to that content from the previous week and work on that material with the student even though the whole group lesson was about new content. Mathematics stations also allowed for opportunities to extend learning. For example, at my teacher table during stations, I had a student who was able to label all of the assigned fractions on number lines, so I was able to challenge her to label new number lines while the other three people in her group continued to work at their level of understanding. A student, Mary, described in her interview that mathematics stations helped her because if she did not understand something from the whole group lesson, once she did it in mathematics stations she would be like, "ohhh, now I understand it!"

Mrs. Oliver's perception of mathematics stations was that they were useful tools to help her better teach her students at the levels that they needed; she was given the opportunity weekly to meet in a small group setting with each student and understand where they were in their learning process. Based on the student interviews and the surveys, the students overwhelmingly did like the stations and materials that we already had for stations. There were multiple suggestions for more time in the popular technology station, or more computers to use. The perceptions of Mrs. Oliver and myself were that we were able to close some academic gaps while we worked with our small groups during mathematics stations.

Behavior Management. While student engagement was high during our stations time, there was still a need for setting expectations and giving reminders for students who needed more structure and prompting to stay on task. From the observations, there were instances when either of the two teachers had to tell a student to adjust their behavior because they were not following station expectations, or they were off task. Reminders from the teacher were needed across the six days of observation for running, yelling, talking to another group, not doing the task in that station, and not working well with others. At the beginning of stations, before we released the students from the carpet, the expectation was set for the time ahead, and often reminders were given about behavior based on how the day was going, or if there was something that went wrong in the previous rotation - like running during transitions. During both weeks of observations, I noticed the amount of time that Mrs. Oliver and myself needed to spend redirecting behavior or being interrupted at our teacher tables by students' behavior or their questions. Examples of this included answering questions, reminding students to stay on task, and helping students solve peer conflicts. Once I was more aware of the amount of times either she or I were interrupted at our small group table or had to address the other groups around the classroom, it was surprising how many times we did have to avert our attention.

I wrote in my research journal about what it could look like to set more concrete expectations and consequences during stations, possibly using CHAMPS charts for each station. On one of the days when the expectations were set more explicitly, there were no behavior issues during the entire stations rotations; on most days, students often had a

smooth transition in between the two rotations of stations when they could get cleaned up and seated on the carpet within the 45 second timer. Mrs. Oliver said that she had seen improvements in the students' problem-solving skills, and she had not had to step in to solve as many problems as she did in the beginning of the year. Through mathematics stations, student's diverse learning needs can be emphasized when students are given expectations and structure (King-Sears, 2007). Students can complete tasks independently of the teacher, while working with a variety of materials either independently or within a small group (King-Sears, 2007).

Managing behavior is a main part of stations. Mrs. Oliver talked about challenging behaviors that occurred at the beginning of the year and that if she did not persist, she could have very easily given up on mathematics stations. She said she needed to find what worked best for her and the students in order to continue using this model. Mrs. Oliver highlighted that it was important to, "begin with the end in mind, and really believe that this is going to benefit my students, and that it is going to benefit me." While there was still a lot of behavior managing that had to occur even when expectations were set, it was possible for the students to be successful even when they needed reminders to fix their behavior. Through the interview with Mrs. Oliver, I could already see her perceptions going from a more negative outlook because of the unsuccessful beginning of mathematics stations, to more positive as she had been able to get to know her students better as learners and as they were beginning to get used to the routine of stations.

Shaping Student Attitudes.   One of the research questions was how do mathematics stations shape student feelings towards mathematics? There was a balancing act between student's positive and negative attitudes during this study. Student's attitudes were positively shaped towards mathematics when they were feeling engaged in the content within each mathematics station, or more importantly, understanding the concept they were learning and practicing. During student interviews and the observations of stations, it was evident that students were enjoying mathematics when they cheered in excitement during a mathematics game, or told me about a time they were successful on a quiz after practicing that concept during mathematics stations. It was also clear that students who were grouped based on their same academic level were more likely to have success in their small group. When students are working within homogenous grouping, Merritt's (2017) findings suggest the students' mathematical skills, confidence, and attitudes improve.

I am disappointed that there were not more concrete examples of how the students now have more positive attitudes towards mathematics because of mathematics stations. I would have liked for the students to have talked more about how they once hated mathematics, or they experienced a lot of mathematics anxiety, and now they are feeling a more positive attitude about mathematics because of their participation in stations. This could have been from a lack of pre-station data since my research study was conducted in the second semester of using mathematics stations.

In instances where I saw the greatest evidence of negative shaped feelings towards mathematics were involving peer conflicts within the small station groups. There was a lack of learning when students were distracted by a disruptive member or off-task behavior. During interviews, five out of six students shared about negative interactions between peers. Regardless of the social issue the students were explaining, the simple fact that there was an association between mathematics stations and form of conflict was discouraging. If the social and relational side of mathematics stations was negative, then I understand how that could easily shape negative feelings towards mathematics because of those experiences.

Implications

In her interview, when asked about what advice she would give to a teacher who is wanting to use mathematics stations, Mrs. Oliver said,

> "I would say definitely give it a try, I mean even if it is half class, half class … something that will just help you see the benefit of it and then just finding what works best for you … think: would this be something that would fit into my classroom? … Even after having it fail the first few weeks, you know I was ready to give up, but just keep an open mind and try something new … I am a firm believer that I will be doing math stations just because of the growth I have seen in my individual students, but also the individual differentiation that I can do."

Teachers are often looking for new ways to keep their students engaged in academic content, and how to best meet their students' needs. Mathematics stations allows for teachers to meet in small group settings with their students at least once a week and then for students to work on skills like problem solving, working with their peers, and interacting with a variety of materials to practice the same concept. If my future students have the potential to be engaged in various activities that help them learn in the way that our students were engaged this year, then I would fully support implementing mathematics stations into my classroom. Even through reminders and strict behavior management, the level of student engagement and interactions with materials was higher during stations than what we saw during whole group instruction.

When students work closely together every day independently of the teacher, it is possible that there are going to be problems. Mrs. Oliver and I have had the discussion multiple times of how we could switch up the small groups because of peer conflicts when we strategically have students grouped based on academic need. For most of the year, we struggled with moving students to different groups because of their levels; however, we found that in week two of observations that the students benefited from being able to work with new people. With any groups of students, a teacher will need to use their own discretion on how they group their students based on academic need and student relationships. Every class is different so finding what works best for you, as the teacher and your students during mathematics stations will take trial and error. A balance between how much the teacher steps in to help students with their conflicts and then leaving the students to problem solve on their own is another necessary task for any teacher. Peer conflicts are

going to happen between students when they are given more independence and responsibility apart from teacher interactions.

Through differentiation, a teacher is able to offer direct teaching to the academic need of the student at that moment. When there are greater small group opportunities within the classroom, the teacher is able to understand what students are struggling with or how they are excelling, and then adjust their teaching accordingly. Not only does a teacher have the ability to group her or his students based on their needs, but also at the teacher station, differentiation can occur specifically between those few students in that group. There were moments that Mrs. Oliver and I both had students within a small group working on different problems at the same time depending on what they understood about that concept. Sometimes our students need reminders that it is acceptable that they are working at their own pace as their minds have gotten clouded by competition and unnecessary comparisons.

Being able to instill independence in the students during mathematics stations takes a lot of managing of their behavior. First, setting up how they should behave during stations, what the process looks like, and what is expected of them takes time and practice. Continuing to assist them with problems that they have in their groups and individually requires behavior management to still be ever present during stations. In our classroom, we experienced a great number of interruptions because of questions that our students had about a station or task. Establishing the expectation that the teacher table cannot be interrupted while a small group is meeting would allow for more focus for all parties. If the students do have a question or concern, there could be a designated student that they can talk to. This student will be one who is specifically chosen because he or she knows what is expected during each station and what the additional directions for that time are. Setting clear expectations and reinforcing those expectations allows for the students to know what is expected of them, and how they can be successful.

A lingering question is the following: do mathematics stations affect academic performance? While this could have been something that I researched, I was more focused on the perceptions and feelings towards mathematics stations. However, when considering whether or not to implement mathematics stations, a teacher must think about how this is going to help his or her students practice and retain mathematical concepts. Is there a connection between the number of station options that students have and how that affects their ability to remember the material? If a student is able to practice her or his mathematics through a game, using technology and with the teacher table, does that increase their chances for academic success?

Conclusion

As I was researching teacher and student perceptions of the use of mathematics stations, I was very aware of what my personal teacher perceptions were of this model. I discovered that in seeing the student engagement and the ability to meet students at their individual academic levels, I could not imagine practicing mathematics content in any other way.

Like Mrs. Oliver encouraged, teachers should try at least one element of mathematics stations to better differentiate and appeal to the different learning preferences of their class. While this model might not be for everyone, I have seen the benefits of trying mathematics stations for the first time, and the effect has been impactful.

About the Author

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Appendix A: Student Survey

Math Station Survey

1. How do you feel about learning math through math stations?

| Very Happy | A Little Happy | A Little Upset | Very Upset |

2. How do you feel about going to math stations each day?

| Very Happy | A Little Happy | A Little Upset | Very Upset |

3. How do you feel about the variety of stations we have?

| Very Happy | A Little Happy | A Little Upset | Very Upset |

4. How would you feel about not having math stations?

| Very Happy | A Little Happy | A Little Upset | Very Upset |

5. How would you feel about doing whole group practice instead of stations?

Very Happy   A Little Happy   A Little Upset   Very Upset

6. How would you feel about having less stations to go to?

Very Happy   A Little Happy   A Little Upset   Very Upset

7. How would you feel about having less materials/games to learn math with?

Very Happy   A Little Happy   A Little Upset   Very Upset

8. How do you feel about the length of time spent in each station?

Very Happy   A Little Happy   A Little Upset   Very Upset

9. If you could change (add or take away) anything about math stations, what would you change?

10. Tell me about how you feel about working with your peers during math stations.

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Appendix B: Interview Protocol for Student Interview

One-on-one Student Interview Protocol

1. What is your favorite part about math stations? Why?

2. What is your least favorite part about math stations? Why?

3. What would make math stations more enjoyable?

4. How would you describe your mood when you are in math stations?

5. What kind of changes would you like to see in math stations?

6. Tell me about how you feel about working with your peers during math stations?

7. Talk to me about how you feel your understanding of the material is once you go through the different stations?

8. Do you think that math stations help you learn better? Why?

9. Do you think that learning math on the computer, then playing a game, then working on a journal activity, etc. helps you understand the material better? Why?

10. Why do you think that it is important to work with different materials or games to learn the same math content?

Questions may vary and additional questions may be asked depending on the answers of the participants.

Appendix C: Interview Protocol for Teacher Interview

Teacher Interview Protocol

1. Why did you choose to introduce math stations this year?

2. Do you think the students enjoy practicing and learning the math content through stations? Why?

3. What would you change in the future based on how this year of math stations is going?

4. Do you think that there should be less or more stations? Why?

5. Do you think there should be more or less time spent in each station? Why?

6. How would you describe your mood during math stations? Why?

7. What changes have you seen in student engagement or understanding of math content since using math stations?

8. How has the use of math stations impacted your math teaching?

9. What has been the best part about implementing math stations into your classroom this year? Why?

10. What has been the most challenging part about implementing math stations into your classroom this year? Why?

11. What advice would you give to a teacher that is wanting to begin using math stations in his or her class?

12. How do you think interacting with the math content in a variety of ways has impacted the students in other subjects or outside of the classroom?

13. Are you happy you decided to implement math stations into your classroom this year? Why?

14. Talk to me about how you decided to group your students? Why did you group them in this way? Will you or would you change up the groups in the future? How and why?

Questions may vary and additional questions may be asked depending on the answers of the participants.

SURVEYING THE LINGUISTIC NEEDS OF TEAM MEMBERS TRAVELING TO PUERTO RICO FOR A SHORT-TERM SERVICE LEARNING TRIP

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Abstract The researchers conducted an informal mixed-methods needs analysis of team members to calibrate a brief language learning experience suited to the participants before traveling from the U.S. to Puerto Rico on a service-learning trip. The purpose of the service-learning trip involved improving the physical conditions, morale, and resources within a selected school. Two participants who expressed interest in attending the service-learning trip (1 middle school student and 1 adult) were interviewed, and the interview results were used to design a brief online survey. While 34 individuals attended the trip, 18 team members (6 middle school students and 12 adults) voluntarily completed the online survey. Quantitative and qualitative survey results were analyzed and used to design a 6-week Spanish language-prep course to better equip the team to reach their service goals while in Puerto Rico.

Keywords: teacher action research, service learning, needs analysis, perceptions of language learning, language teaching

Introduction

Educators conduct action research to enhance their teaching practice and promote achievement (Cohen, Manion, & Morrison, 2011; Mertler, 2016). In education, action research is, "intended to support [teacher] researchers in coping with the challenges and problems of practice and carrying through innovations in a reflective way" (Feldman, Altrichter, Posch, & Somekh, 2018, p. 6). To this end, needs analyses can demonstrate a crucial component to exposing learners' beliefs, attitudes, and goals regarding a target language and culture (Long, 2005; Wei, 2016). The revealed learner needs may direct

educators' planning and empower them to conduct a course better suited for their students.

The researchers for this study served as team leaders for a group of 34 people, comprised of middle school students and adults in the U.S., who traveled to Puerto Rico for one week on a service-learning trip. Service-learning involves, "experiential learning and allows students first-hand immersion with a culture, different than their own, leading to greater awareness and an increased sense of cultural competence" (Wall-Bassett, Hegde, Craft, & Oberlin, 2018, p. 275). While in Puerto Rico, the team members were expected to participate in projects to improve the conditions of a specific school (through painting, mulching, electrical work, etc.), teach and entertain students with creative games, perform dramas and musical productions, and provide resources to enhance the learning environment of the school.

When traveling outside of one's cultural and linguistic locality, one must have a healthy awareness of the target language and culture to reap a positive experience. The researchers, as facilitators of the service-learning trip, recognized that fostering cultural awareness and sensitivity among team members would enable them to better serve the people of Puerto Rico (Wall-Bassett et al., 2018). To ensure the principal success of this experience, the researchers offered a prep course in Spanish language and Puerto Rican culture to interested participants. Kaewpet (2009) argues, "learner needs will need to be addressed if the course is to be successful" (p. 209).

To clarify learner needs, beliefs, and culture as discussed in this study, the following descriptions are provided. *Learner needs* constitute the gap between what learners currently know and the knowledge they hope to attain (Hutchinson & Waters, 1987; Kaewpet, 2009; Long, 2005). Learners' *belief systems* are explained by Richards and Lockhart (1996) as able to, "influence learners' motivations to learn, their expectations about language learning, their perceptions about what is easy or difficult about a language, as well as the kind of learning strategies they favor" (p. 52). Therefore, the ideology one has regarding a language can completely alter the individual's approach to learning that target language. In the same way, a learner's perspectives regarding a target culture can influence his or her approach to learning the language. Here *culture* is defined in accordance with Lobo (2005) as, "an aspect or feature that can be associated with life in a country, including its language" (p. 35).

Therefore, the purpose of this study was to discover the linguistic needs and perceptions of the team members. Learners' current knowledge, needs, and beliefs were assessed using interviews and surveys to gather qualitative data (Griffin, 2016; Harlow, Smith, & Garfinkel, 1980; Kouritzin, Piquemal, & Renaud, 2009; Lobo, 2005). Results from preliminary or exploratory interviews with one adult and one student, both of whom had expressed interest in attending the service-learning trip, were utilized to design research survey questions (Mertler, 2016; Kouritzin et al., 2009; Lobo, 2005). The two interviewees were available and volunteered to be interviewed during the exploratory stages of the action research. Specifically, the researchers sought answers to the following questions:

1. How much Spanish do the team members attending the trip know and what can they do now?

2. What do the team members believe they need to know and do in the target language and culture?

3. How do the team members believe they can achieve their linguistic and cultural goals?

Literature Review

Needs analysis, as a form of action research, has been found effective in assessing the needs and motivation of language learners (Long, 2005). In the field of language teaching, needs analyses have focused on what learners need to more efficiently learn for a target language. The results from such analyses have been used to write language objectives, design syllabi, and decide on appropriate teaching and assessment methods and resources for language courses (Wei, 2016). Three studies conducted over the last 40 years that have ramifications for the present study are discussed here.

Harlow et al. (1980) administered a survey to 250 first-semester students of French regarding perceived communication needs. This survey included three parts: biographical information, plans of how students might use French in the future, and rated descriptive statements regarding categories of language use. In the final section, students were asked to rate the statements using a Likert scale, measuring the individual's judgment of the item's importance. The purpose of this study was to identify a means to, "compose a syllabus, based upon concrete data, which [would be] patterned after the functional/notional concept" (Harlow et al., 1980, p. 11). This research constituted a basis for this study's design, as similar survey results were used to design a fitting language-prep course for team members traveling to Puerto Rico. This course was designed with a functional/notional syllabus, which aligns with the research of Harlow et al. (1980), insofar as it, "entails a structuring of language and language teaching in terms of content rather than form, and learner needs rather than tradition" (p. 12).

Students enrolled in undergraduate Korean as a foreign language (KFL) courses at the University of Hawai'i participated in a needs analysis (Chaudron et al., 2005). Researchers first conducted unstructured interviews with a random sample of students (n = 21; 25%) enrolled in Korean language courses during the first semester, and findings from the interviews were used to design a survey that was administered to all participants (n = 84). Survey respondents reported, among other things, a strong desire to learn Korean to better communicate with friends and relatives, to advance in their careers, and to conduct themselves more successfully when touring South Korea. The researchers then paired with curriculum developers to design "social survival" language learning tasks that met the learning needs of over 90% of the KFL students. Likewise, the researchers for the present study used results from semi-structured interviews to create a relevant survey, and the survey results were used to design effective Spanish language curricula matched to learner needs.

A more recent study was designed to assess the needs of native Arabic-speaking engineering students of English for specific purposes (ESP) (Alsamadani, 2017). Classroom observations, semi-structured interviews, and a survey were utilized with student participants (*n* = 200) at Umm Al-Qura University in Saudi Arabia. One noticeable finding was that students reported the need for greater emphasis on meaningful speaking and writing skills in ESP courses. In general, participants wanted to learn English in a way that was responsive to their needs. They were not interested in gaining a "'textbook' type of knowledge" (Alsamadani, 2017, p. 65) of English but wished to gain meaningful proficiency to use English in the professional and business worlds. Responding to Alsamadani's (2017) call for more "pervasive and comprehensive 'needs analysis' . . . [to] motivate students to become actively involved in the process of learning" (p. 65), the researchers in the present study sought to design a comprehensive analysis of team members' learning needs and design a functional/notional syllabus based upon those needs.

Methodology

Subjects. In the past 25 years, short service-learning trips have become an increasingly popular experience for students in the United States. The trip under study consisted of 34 team members (17 adults, each accompanied by one of their children) as well as two team leaders, the action researchers. Initially, the researchers conducted interviews with two potential team members who had expressed interest in attending the service-learning trip, the results of which were utilized during the preliminary stages of the research to construct a survey for the remaining individuals on the team. Though the survey was distributed to all 34 team members, 18 participants elected to complete the survey regarding their linguistic and cultural beliefs, needs, and goals. The student participants were classmates at a private institution in an affluent suburb in the southeastern U.S. Public and private schools in the local area are regionally renowned for the competitive level of academics.

Data Collection. To investigate the cultural and linguistic needs of the team members, the researchers administered two interviews and 34 surveys. The open-ended individual interview sessions with two team members served to gage the participants' beliefs, attitudes, self-reported proficiency, and goals regarding the Spanish language and Puerto Rican culture. The responses from these recorded face-to-face interviews were recorded, transcribed, and analyzed to provide direction for the formulation of appropriate survey questions (see Appendix A).

To streamline the accessibility and anonymity of the survey for participants, the researchers designed and administered the survey through an online survey management site. Email constituted a significant means of communication for the team prior to departing on the service-learning trip; therefore, a link to the survey was emailed to each team member. The survey consisted of nine questions, a length deemed appropriate to elicit increased likelihood of participant responses (see Appendix B). As mentioned above, although all 34 team members were given the opportunity to complete the survey, 18 participants provided responses. The data were assessed and compared to construct an appropriate language-prep mini-course for the service-learning trip to Puerto Rico.

Data Analysis. The survey served as a needs analysis assessment tool. Data collected from the survey informed the development of a program of study for the team to ensure that they were linguistically and culturally prepared for their upcoming trip to Puerto Rico. Therefore, the researchers categorized the commonalities of the participants' itemized responses and constructed corresponding lessons. Although 18 of the 34 team members submitted survey responses, the data collected account for over half of the team (53%). For action research with small sample sizes in educational settings, this is a sufficient pool of representation for a needs analysis, with a confidence level of 95% and a confidence interval of ±16% (Cohen et al., 2011). The common results discovered in team members' responses outlined the framework for the language-prep program subsequently designed.

Results

To determine the level of Spanish proficiency among the participants, the team members self-identified their knowledge of Spanish on the survey. Therefore, their language capabilities were not officially tested, and this analysis was based upon the assumption participants provided honest answers. This assumption was reasonable given that the surveyed team members were not graded or in any way consequently affected by the responses provided through this survey.

Prior Language Learning Experiences. To determine the level of Spanish proficiency among the participants, the following interview question provided the clearest results: "Have you studied Spanish in the past? If so, where and for how long?" One of the two interviewed participants responded that he had never studied Spanish, while the other stated he had studied Spanish for two years over two decades ago. Therefore, the following two pieces were included on the survey. The first item was an open-ended question that asked participants to briefly describe their language learning experience. While seven participants did not respond to this term, the following responses were received:

- "It's been too long ago – high school."
- "Started studying Spanish this year"
- "I work with a Spanish speaking employee, so I know a few words."
- "2 years of high school foreign language"
- "1 semester in college 20 years ago"
- "I have not learned any Spanish yet"
- "6th grade ½ semester"
- "Studied in college"
- "Brothers that speak Spanish"
- "Only about 2 ½ years"
- "5 years in a Spanish speaking country"

These responses demonstrate the predominantly novice base of language learners comprising the team, apart from the two individuals who studied for over two years and lived in a Spanish-speaking country for five years. To further examine learner capabilities, the researchers asked team members to identify themselves as beginning, intermediate, or advanced language learners through completion of the sentence: "I am ___." The results are shown in Figure 1 below.
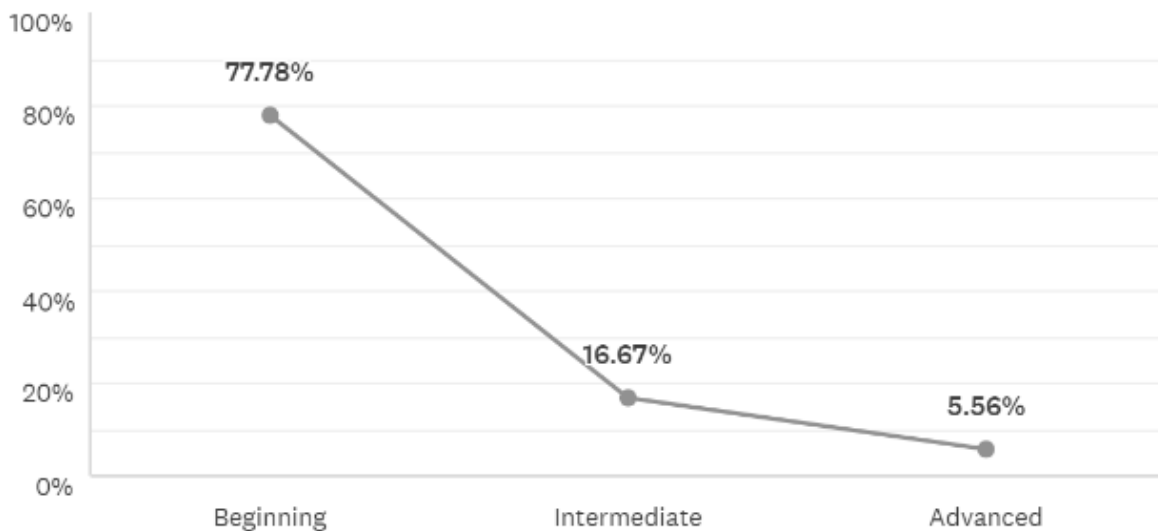
Figure 1. Perceptions of Current Spanish Language Proficiency.

One team member (5.56%) reported herself being comfortable speaking in Spanish, which we denoted as perceiving *advanced* proficiency. While three participants (16.67%) described their current Spanish language skills as falling into the *intermediate* proficiency category, most respondents (77.78%; *n* = 14) indicated that they knew little to no Spanish and were at the *beginning* level of Spanish proficiency.

When asked to select items from a list of what they currently can do in Spanish, the surveyed participants responded as summarized in Table 1 below.

Table 1: Perceptions of Current Spanish Language Skills

Choice	*n*
Greet people in Spanish	93% (14)
Understand and demonstrate respectful Puerto Rican etiquette	60% (9)
Ask where to find the restroom	60% (9)

Order food at a restaurant in Spanish	20% (3)
Ask for basic directions	20% (3)

One individual left a comment stating, "none of the above," and three others skipped this question. These four individuals all claimed to be willing to invest time in online lessons and activities in language and culture for one hour per week. Likewise, of the five team members who said they were only able to greet people in Spanish, two were willing to spend a half hour per week to work on Spanish language and Puerto Rican culture, while one expressed willingness to commit one hour per week, and the remaining participant selected 3–5 hours per week. All five respondents who claimed to only be able to greet people in Spanish also expressed interest in online lessons and activities above all other forms.

These results depict that most service-learning trip team members were either very novice learners or did not yet consider themselves Spanish learners but were open to learning to various degrees. In response to this needs analysis, initiating the prep course with basic Spanish words and phrases seemed most beneficial for the team. This starting point was intended to inform the new learners and refresh those who had learned the basic material before.

Perceptions of Language Learning Goals. To determine what team members believed they needed to know and do in the target language and culture, the survey inquired as to what participants would like to be able to do in Spanish once they arrived in Puerto Rico. Respondents stated a need to know basic words and a desire to participate in basic conversations with Puerto Ricans. Therefore, the survey included an item inquiring about team members' ratings regarding the importance of various basic communicative Spanish features. The results from this section of the survey are displayed below in Table 2.

Table 2: Perceptions of Value of Language Learning Outcomes

	Level of Importance					
	Not (1)	*Somewhat (2)*	*Very (3)*	*n*	*M*	*SD*
Greeting people in Spanish	0% (0)	17% (3)	83% (15)	18	2.83	0.37
Demonstrating respectful etiquette while in Puerto Rico	0% (0)	6% (1)	94% (17)	18	2.94	0.23

Ordering food at a restaurant in Spanish	11% (2)	50% (9)	39% (7)	18	2.28	0.65
Asking for basic directions	0% (0)	67% (12)	33% (6)	18	2.33	0.47
Asking where to find the restroom	17% (3)	33% (6)	50% (9)	18	2.33	0.75

A preliminary interview question asked whether participants would be willing to take a language and culture prep course, and if so, what format they would prefer. With positive responses regarding the course and a declared preference of audio and speaking formats, items were included on the survey asking respondents to select what lesson delivery or learning formats they would prefer and how much time they were willing to devote to learning. Participants were able to select multiple answers regarding the learning format, but only one response for the item about time commitments. Respondents described wanting to invest time in a language and culture training in a variety of formats (Figure 2), though students preferred small classes ($n = 12$; 67%) and online activities ($n = 8$; 44%) above other formats.
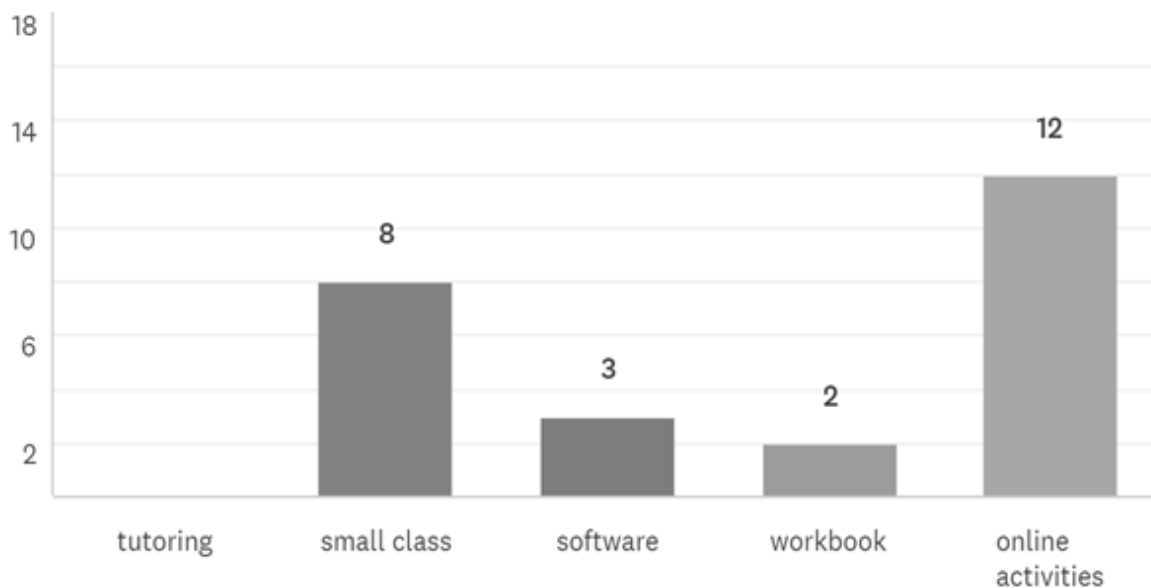
Figure 2. Spanish Language Study Learning Format Preferences.

When asked "How much time per week would you be willing to devote to working on your Spanish language and culture learning?" team members responded in accordance with the data viewable in Figure 3 below, with the majority selecting either a half hour or one hour ($n = 15$; 83%). With dominant interest in online and small class formats of no more than one hour per week, the prep course design adhered to these results. Practical qualities, such as the availability of the team leaders, the pre-set meeting dates, and meeting space availability, all influenced the realistic construction of the prep course. With the data and

logistics considered, the prep course entailed a 30-minute small class gathering before each of the six informational trip meetings, during which online materials and sites were provided for short at-home practice activities and exercises lasting no longer than 30 minutes.
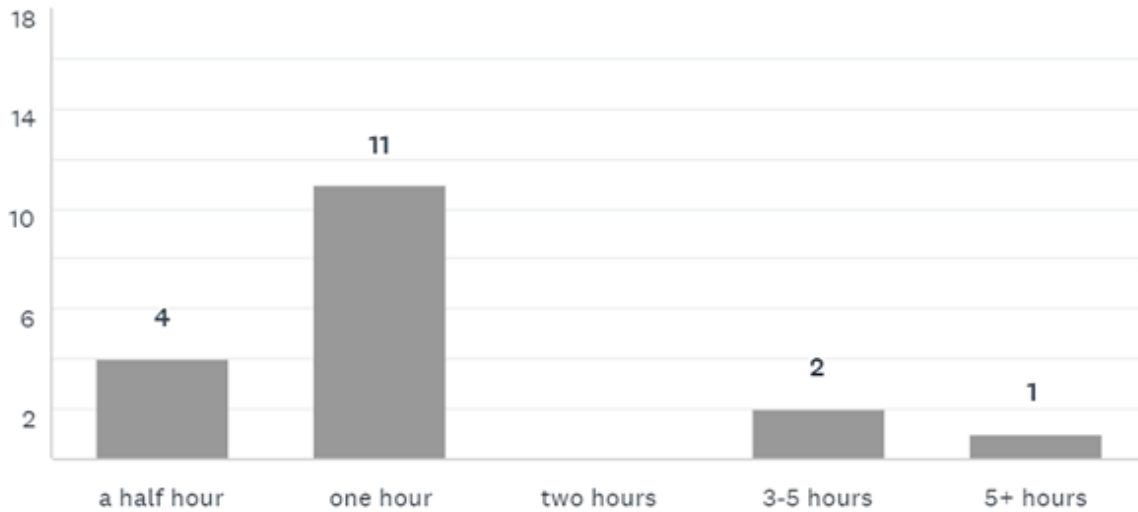
Figure 3. Time Commitments to Spanish Language Study.

Perceptions of Aptitude and Value of Language Learning. To better understand the participants' language learning beliefs, they were asked to rate their level of agreement with statements concerning their perceptions of their own language learning skills and the value they placed on learning Spanish. Statements included for this item and the results are shown in Table 4 below.

Table 4: Perceptions of Current Language Learning Skills

	Scale of Agreement						
	Strongly Disagree (1)	*Disagree (2)*	*Agree (3)*	*Strongly Agree (4)*	*n*	*M*	*SD*
I'm a good language learner.	6% (1)	44% (8)	33% (6)	17% (3)	18	2.61	0.83
I'm good at Spanish.	33% (6)	56% (10)	6% (1)	6% (1)	18	1.83	0.76
I don't think many PRs will be able to speak English.	28% (5)	33% (6)	39% (7)	0% (0)	18	2.11	0.81
Learning Spanish is useful.	0% (0)	6% (1)	61% (11)	33% (6)	18	3.28	0.56

Learning Spanish is difficult.	12% (2)	29% (5)	53% (9)	6% (1)	17	2.53	0.78
I'm not willing to work hard to learn Spanish.	25% (4)	50% (8)	25% (4)	0% (0)	16	2	0.71
The culture in PR is inviting.	0% (0)	0% (0)	83% (15)	17% (3)	18	3.17	0.37

Beliefs about themselves as language learners. The interviews inquired as to whether participants saw themselves as good language learners and why. The interviewees defined themselves as good language learners due to natural ability to learn quickly. Therefore, the survey included items assessing team members' beliefs about themselves as language learners.

Half of the surveyed participants (*n* = 9; 50%) identified themselves as good language learners, while the other half of the group declared otherwise. Most participants indicated that they were not proficient in Spanish (*n* = 16; 89%). Roughly 67% (*n* = 12) of the team members who rated the statement about willingness to challenge themselves indicated they were willing to work hard to learn Spanish, which empowered the efforts of designing this functional/notional syllabus because the participants expressed buy-in and interest. As informed by the data, the researchers decided to begin the prep course with a class containing less complex but meaningful learning activities. Team members with greater Spanish proficiency were expected to boost the confidence and motivation of less-proficient team members to help them better engage in the Spanish learning process. Providing materials and lessons within the team members' zones of proximal development was central to the overall intent of the prep course and helped to maintain a balance between challenging and attainable goals in the learning process. When students believe they can learn, they will try harder; therefore, this balance between rigor and motivation was necessary to ensure students remained engaged and confident in themselves as language learners.

Beliefs about language learning. When questioned about the challenges associated with language learning, the interviewees responded that the difficulty depends on the individual language learner. Therefore, the survey included a question asking if participants agreed or disagreed that learning Spanish is difficult. Approximately 60% of the team members agreed that learning Spanish is difficult, and about 40% disagreed. Nonetheless, more than 90% of the team members stated they believed learning Spanish is useful.

These reported beliefs about language learning informed the development of the prep course. The beginning of the course was purposefully designed to help participants recognize the usefulness of Spanish and to provide linguistic tools and materials suitable for the team's pace of learning. The team leaders attempted to demonstrate that learning Spanish is not overly difficult and unattainable. While learning Spanish, or any language, is not easy, the format and pace of instruction can be used to enhance learners' acquisition and learning experiences.

Beliefs about culture learning. To determine team members' cultural goals and beliefs, the interviewed participants were asked what they wanted to learn about the Puerto Rican culture. Both interviewees stated a desire to learn Puerto Rican customs and etiquette. Consequently, the survey included a question asking if team members believed that demonstrating respectful etiquette while in Puerto Rico would be important, and all participants agreed that this was significant. Therefore, the prep course included useful details about Puerto Rican customs and etiquette.

Discussion and Implications

The process of formulating the functional/notional syllabus in this study was intended to serve as a practical example for language educators at all levels. Purposefully aligning objectives embedded in a course with student perceptions and needs can promote greater student engagement and achievement (Jabbarifar & Elhambakhsh, 2012). Analyzing needs to inform syllabus construction as it pertains to the broader field of education is also central to this discussion.

The discoveries of this action research culminated in the formation of a prep course for a service-learning trip going to Puerto Rico. The goal of this course was to engage all team members in acquiring Spanish language and learning about Puerto Rican culture. When choosing the length of the course, the collaborating researchers took into consideration team members' lifestyles and other responsibilities. Additionally, survey results indicated most team members preferred to learn Spanish language and culture online and/or in a small class for no more than one hour per week. To promote participation, the prep course entailed short 30-minute small class sessions held before mandatory informational trip meetings. Additional online materials were provided at each session for at-home practice and study. One of the action researchers taught the small class and prepared all the handouts and other necessary materials. Participants were encouraged to reach out if they desired to schedule individual tutoring.

The needs analysis indicated that most team members predominately had little to no Spanish learning experience prior to the service-learning trip. Therefore, the course launched with a study of the Spanish alphabet and pronunciation (see Appendix C for the course syllabus). The initial lessons also incorporated a brief introduction to Spanish language and culture. Less-complex introductory language activities were included to ensure that the learning objectives were attainable for most participants with little Spanish proficiency. These activities were chosen to ensure team members experienced language learning success and increased confidence, thus encouraging the continuation of learning (Tsai, Cheng, Yeh, & Lin, 2017).

Just over half of the team members believed learning Spanish was difficult, though the clear majority recognized it to be useful. Therefore, the course was designed for the needs and feasible learning pace of the service-learning team members to demonstrate that learning Spanish is attainable. Addressing the learner beliefs surrounding the course content in this

way exhibited the team leaders' commitment to accommodating the students they served. Womack (2017) maintained that syllabi and course objectives should be designed with all students in mind to undergird the course with accommodations appropriate for the target audience. Accommodating students' needs and learning goals when designing a course—what Womack (2017) termed *universal design*—is a necessary means for appropriate and effective instruction.

To further employ the practice of universal design throughout the construction of the prep course, each element of the survey informed a lesson for the course. Participants declared the following linguistic features to be important: greeting people in Spanish, demonstrating respectful etiquette, and asking where to find the bathroom. Teaching and practice of these linguistic and cultural aspects were incorporated into the prep course curriculum. The second session covered greetings and basic questions, and the third lesson explored ordering food in a restaurant. The prep course also incorporated details about Puerto Rican customs and etiquette in the fourth lesson. The fifth lesson covered asking for directions and where to find the restroom. Likewise, educators who wish to promote student success and self-efficacy may find the results of a preliminary needs-analysis, like the one employed in this study, helpful.

Though the team members would have benefited greatly from conversing in Spanish while in Puerto Rico, a 6-week course of one hour per week did not lend itself to adequate preparation for advanced sentence formation. The prep course instead included a wealth of basic communicative phrases that team members could practice and use to communicate with Puerto Ricans. During the service-learning trip, the team hosted drama and musical performances, all of which had translators. However, the team was equipped with phrases to invite Puerto Ricans to these programs in Spanish. The course sought to meet the needs of the students as practicable in the time frame allotted for the class—a measure suggested for educators employing a similar approach to syllabus and course design.

Conclusion

This needs analysis was conducted to design an appropriate preparation course for a service-learning team. The process of creating a functional/notional syllabus informed by learner needs proved to be daunting for the teacher researchers and required significantly more effort than utilizing a pre-designed textbook. Nonetheless, the anticipation remained that the resulting prep course would enhance student learning.

Employing universal backwards design by utilizing the results of a needs analysis to formulate objectives and design a "best-fit" course for students serves as a means of preliminary accommodation (Womack, 2017). Like Serafini and Torres (2015), the action researchers in this study anticipation that our, "needs analysis can provide practitioners with an adaptable blueprint to implement their own needs analysis," (p. 465) while designing a specialized course. The interview and survey utilized in this study are examples for other educators who may wish to employ a similar informal needs analysis for a course or unit and may be adapted to suit a different context for learning.

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Appendix A: Preliminary Interview Questions

1. Have you studied Spanish in the past? If so, where and for how long?

2. So tell me what got you interested in going on this trip.

3. What will you need to do in Spanish when you get to Puerto Rico?

4. What would you like to be able to do in Spanish with you get there?

5. Would you say that you are good at learning languages? Why or why not?

6. Do you think certain formats of learning a language would be preferable to you?

7. Do you think language learning is hard?

8. What comes to mind when you think of the culture in Puerto Rico?

9. Do you want to learn about the Puerto Rican culture? If so, what do you want to learn?

10. How might you gain the desired knowledge of the Spanish language and Puerto Rican culture before your trip?

11. Would you be willing to take a prep course of Spanish language and Puerto Rican culture before your trip? Why or why not?

Appendix B: Survey Protocol

1. Please complete each demographic indicator below:

Name: _____

Age: _____

Gender: _____

Level of education: _____

2. Please complete each item below:

Language(s) spoken: _____

Language(s) studied: _____

Location(s) of past travel to

Spanish-speaking localities: _____

Amount of time spent abroad: _____

3. Please indicate whether you (1) *strongly agree*, (2) *agree*, (3) *disagree*, or (4) *strongly disagree* with the following statements:

_____   I'm a good language learner.

_____   I'm good at Spanish.

_____   I don't think many Puerto Ricans will be able to speak English.

_____   Learning Spanish is useful.

_____   Learning Spanish is difficult.

_____   I am not willing to work hard to learn Spanish.

_____   The culture in Puerto Rico is inviting.

4. Check only one choice to complete the following statement:

I am . . .

_____   fluent in Spanish

_____   comfortable speaking in Spanish, though I struggle sometimes

_____   able to understand more Spanish than I can speak

_____   not comfortable speaking in Spanish, but I can read and write some Spanish

_____   able to say a few basic words in Spanish

_____ not currently able to communicate in Spanish at all

5. Briefly describe your Spanish language learning experiences.

_____

_____

_____

6. Select whether you believe the following features are (1) *very important*, (2) *somewhat important*, or (3) *not important*.

_____ greeting people in Spanish

_____ demonstrating respectful cultural etiquette

_____ ordering food at a restaurant in Spanish

_____ asking for basic directions

_____ asking where to find the restroom

*Other (please specify):   _____

7. Check all choices that answer the following statement:

I'm able to . . .

_____ greet people in Spanish

_____ understand and demonstrate respectful Puerto Rican etiquette

_____ order food at a restaurant in Spanish

_____ ask for basic directions

_____ ask where to find the restroom

*Other (please specify):   _____

8. Check all choices that answer the following statement:

I would invest time in a language and culture training in the form of . . .

_____ tutoring

_____ a small class

_____ software

_____ a workbook

_____ online lessons and activities

*Other (please specify): _____

9. Check <u>only one</u> choice to answer the following question:

How much time per week would you be willing to devote to working on your Spanish language and culture learning?

_____ ½ hour

_____ 1 hour

_____ 2 hours

_____ 3–5 hours

_____ 5+ hours

Appendix C: Prep Course Syllabus and Outline

Prep Course Overview

This course is designed to prepare our team to have the most beneficial service-learning trip possible. During this course we will learn the basics of Spanish language and Puerto Rican culture. This course was designed in response to the results of the survey our team members completed. Therefore, this course has been specifically designed for adults and adolescents to learn together. These six sessions are convenient, as they will take place just before our team meetings. Also, the material will be engaging and fun as we learn about the Spanish language and Puerto Rican culture together.

Dates of Meetings

Date	Location	Time
Sunday, April 26, 2017	Room A	9:00 - 9:30 a.m.
Wednesday, March 1, 2017	Room B	5:30 - 6:00 p.m.
Sunday, March 5, 2017	Room A	9:00 - 9:30 a.m.
Wednesday, March 8, 2017	Room B	5:30 - 6:00 p.m.
Sunday, March 12, 2017	Room A	9:00 - 9:30 a.m.
Wednesday, March 15, 2017	Room B	5:30 - 6:00 p.m.

Texts

- Spanish-English Dictionary

Frequently Used Websites

- Puerto Rico governmental site: http://www.topuertorico.org/

- BBC Spanish language site: http://www.bbc.co.uk/languages/spanish/talk/

- Spanish language class site: http://mendycolbert.com/Spanish1.htm

- Spanish practice site: http://www.studyspanish.com/

Course Outline

Lesson Topic	Lesson Objectives	In-class Learning Tasks	At-home Practice Activities	Online Resources
Session 1: Introduction to Spanish Language and Hispanic Culture	To be able to explain the value in learning the Spanish language and culture for our service-learning trip to Puerto Rico To understand the outline and design of this course To be able to pronounce letters in the Spanish alphabet	1. Discuss the value in learning Spanish and culture for our service-learning trip. 2. Review the outline and design of this course and ask and answer questions. 3. Introduce Spanish alphabet with videos and handouts (see resources). 4. Discuss the at-home activities.	With your family member: 1. Search the web to discover interesting cultural features of Puerto Rico and bring your findings next week. 2. Practice your pronunciation using the provided online resources.	Chart: Spanish Alphabet Exercise: Spanish Pronunciation Practice Web site: Official Puerto Rico Governmental Site Video: Spanish Alphabet Video: Practice Spanish Alphabet Song
Session 2: Greetings and Basic Questions	To be able to greet someone in Spanish To understand the greetings and salutations of others To be able to speak and respond appropriately in formal v. informal situations	1. Discuss cultural findings from last week's at-home activity. 2. Review pronunciation. 3. Introduce basic Spanish greetings with videos and vocabulary handout (see resources). 4. Complete partner communicative activity (see resources). 5. Discuss the at-	With your family member: 1. Re-watch the basic greetings videos (see resources). 2. Write three basic conversations. 3. Complete the at-home activity (see resources).	Handout: Greetings Lesson Vocabulary Partner Communicative Activity: Greetings Lesson 2 Vocabulary Flashcards Conversational Activity Video: Basic Greetings, Part 1 Video: Basic Greetings, Part 2 Video: Formal v.

		home online practice activities.		Informal Language
Session 3: Ordering Food in a Restaurant	To be able to order food in a restaurant or other food establishment	1. Begin with reading and reviewing greetings and basic conversations (from last week's at-home activity). 2. Discuss the progression of interactions between customers and waiters on the mainland U.S. and how they differ from those in Puerto Rico. 3. Watch the video explaining how to order food at a restaurant. 4. View and discuss the food vocabulary handout (see resources). 5. Complete the dictionary usage activity handout (see resources). 5. Discuss the at-home online practice activities.	With your family member: 1. View the at-home activity link (see web links). 2. Create a menu together and role-play as a server and customer ordering from the menu. 3. Take turns switching roles and check each other's Spanish.	Handout: Foods Lesson Vocabulary Activity: Dictionary Usage Lesson 3 Vocabulary Flashcards At-home Communicative Activity: Menus Video: How to Order Food or Drinks in Spanish
Session 4: Puerto Rican Culture and Etiquette	To be able to understand culturally respectful etiquette in Puerto Rico	1. Practice greetings and basic questions. 2. Review last week's at-home activity of how to	With your family member: 1. View the three websites provided that explicate Puerto Rican	Article: Puerto Rican Cultural Etiquette Puerto Rican Etiquette Puerto Rican Culture

		order food in a restaurant. 3. Discuss the importance of demonstrating respectful etiquette. 4. Together read the article regarding Puerto Rican etiquette (see resources). 5. Read the articles about Puerto Rican etiquette (see resources). 5. Discuss the at-home online practice activities.	culture and etiquette (see resources). 2. Discuss the Puerto Rican culture and etiquette together 3. Practice previously learned material.	
Session 5: Useful Miscellaneous Words and Phrases	To be able to invite someone to a program To be able to exchange pleasantries and greetings To be able to ask for and understand directions To be able to ask where to find the restroom	1. Discuss principles of Puerto Rican etiquette. 3. Overview of invitations vocabulary flashcards (see resources). 4. View videos and discuss how to ask for directions (see resources). 5. Complete Asking for Directions Activity (see resources). 6. Watch and discuss the video on asking where to find the	With your family member: 1. Practice inviting someone to a program and wishing them a good day. 2. Role play to practice asking for directions and giving directions. 3. Practice asking and telling where to find the restroom.	Invitations Vocabulary Flashcards Videos: Asking for Directions Activity: Asking for Directions HYPERLINK "https://www.youtube.com/watch?v=AGW8Tt8PCoc&noredirect=1" Video: Where is the Restroom?

		restroom (see resources). 7. Discuss the at-home online practice activities.		
Session 6: Course Review	To review learned material and answer any questions	1. Discuss the value of learning Spanish and Puerto Rican culture for our service-learning trip. 2. Perform impromptu skits of exchanging greetings and asking basic questions. 3. Choose three different partners to practice ordering in a restaurant. 4. In a small group, discuss Puerto Rican culture and etiquette for five minutes. 5. In a new small group, role-play asking for directions and asking where to find the restroom. 6. As a class, discuss situations in which we might use the conversational phrases presented in the last lesson.	With your family member, practice the material covered in the course and review the vocabulary overview handout (see resources).	HYPERLINK "http://www.phschool.com/atschool/realidades/pdfs/repaso/L1_Capitulo_PE.pdf" Handout: Vocabulary Overview

DEVELOPING CRITICAL THINKING, JUSTIFICATION, AND GENERALIZATION SKILLS IN MATHEMATICS THROUGH SOCRATIC QUESTIONING

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Abstract This article reports on an action research study, which explored the impact of Socratic questioning on student learning in a second-level mathematics classroom in Ireland.   While students engaged in a higher order mathematical task – the tower problem (Martino & Maher, 1999), the teacher used Socratic questioning techniques to challenge and support them to justify and generalize the problem as well as their thinking processes and solutions. The results of this study point to strong links between strategic Socratic questioning and students' involvement in critical thinking, justification, and generalization.

Keywords: teacher action research, Socratic questioning, mathematics education, justifications, generalizations, higher order thinking

Note: This action research study was conducted by Meighan Duffy during the final year of her Bachelor in Mathematics and Education programme at the National University of Ireland Galway. Manuela Heinz acted as Meighan's research supervisor, supporting her throughout the development, implementation and writing of the research and this paper.

Introduction

To question well is to teach well. In the skilful use of the question, more than anything else, lies the fine art of teaching (De Garmo, 1911)

This article will explore the area of questioning in the mathematics classroom. As a preservice mathematics teacher, I[1] have begun to analyze my questioning practices. From my observations of mathematics teachers during my initial teacher education, I have noticed a strong emphasis on repetition, convergent one-answer thinking and drill like procedures.

A variety of research studies indicate that mathematics teachers are not particularly adept at asking questions (Aizikovitsh-Udi, 2013). Watson and Young (1986) found that teachers ask as many as 50,000 questions a year while their students ask as few as 10 each (as cited by Vacc, 1993). As well as that, "about 60% of teachers' questions require students to recall facts, about 20% require students to think, and the remaining 20% are procedural" (Gall, 1970, p. 713).

It is argued that the over emphasis on covering material as opposed to engaging students' thinking is a result of teachers not fully appreciating the role of questioning in the development of subject knowledge. Many teachers assume that answers can be taught separately from questions (Elder & Paul, 1998). As a preservice teacher, I can relate to this misconception. On numerous occasions I have reflected on lessons and found my use of questioning to be very superficial and, at times, meaningless.

This action research study was inspired by my desire as an educator to help students to reach their fullest potential by making mathematics meaningful and relevant to their lives and interests. In order to fulfil my hopes and philosophy of education, I realize the importance of examining the types of questions I ask in the classroom and the educational objectives they can help my students and I to achieve. I believe that a greater understanding of questioning can allow me to encourage critical thinking amongst my students, thus making me a better educator.

In my research, I explored how I could use Socratic questions to enhance my students' critical thinking, generalization and justification skills in the mathematics classroom.

Literature Review

Classroom questions have been classified in many different ways by various researchers. According to Gall (1970) there are at least 11 classifications of question types. However, mathematics classroom questions can be simplified to fall into one of two overarching categories: lower cognitive questions and higher cognitive questions. Lower cognitive or lower order questions are predominately used to determine students' ability to recall information previously read or taught by a teacher with answers generally predetermined and fixed. These questions are sometimes referred to as convergent questions and correspond to the level of 'knowledge' outlined in Bloom's taxonomy (Winnie, 1979). Higher cognitive or higher order questions, on the other hand, encourage students to think past the simple literal answering of questions, engaging them deeply with what is being asked to extend their understanding. The responses associated with these questions coincide with

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[1] Throughout this article, the first person pronoun "I" refers to Meighan who, at the time, implemented this study as a preservice teacher during her last block of school placement.

'application', 'analysis', 'synthesis', and 'evaluation' levels in Bloom's taxonomy (Winnie, 1979).

A model of questioning that is based on the use of higher cognitive questions is the 'Socratic Model of Questioning'. According to Paul and Elder (2007, p. 2), "the key to distinguishing Socratic questioning from questioning per se is that Socratic questioning is *systematic, disciplined,* and *deep,* and usually focuses on foundational concepts, principles, theories, issues, or problems". Essentially, Socratic questioning or Socratic dialogue is about probing thinking at a deeper level. Cox and Griffith (2007) also emphasised the importance of integrating Socratic questions and identified six categories:

1. Getting Students to clarify their thinking: 'Could you expand on that?', 'Why do you say that?'
2. Challenging students about assumptions: 'Does that always happen?', 'Why do you think that application applies here?', 'Is this always the case?'
3. Evidence as a basis for argument: 'What are the reasons behind your answer?' 'Why do you say that?'
4. Alternative viewpoints and perspectives: 'Did anyone answer this differently?'
5. Implications and consequences: 'What can you conclude from this proof?', 'How does …. effect ….?'
6. Question the Question: 'Do you think that was a relevant/important question?', 'Why do you think I asked that question?', 'Which of your questions turned out to be most useful?'

Using classroom questions to promote justifications and generalizations. Davis et al. (1992) found that when students are given a problem to work on independently they begin by building their own representation and solution, and when they have achieved this, they are usually interested in the ideas of, and in communicating ideas with, others. Once students believe their result is valid, they are ready to justify and generalize their solution. This is when teacher intervention is crucial (Martino & Maher, 1999). Martino & Maher (1999) found that, in general, students do not naturally seek to build a proof or justify their findings. Rather, students usually believe that finding a solution is enough.

A very important factor when learning mathematics, or any subject, is making connections with knowledge already acquired. Questions that invite students to make mathematical connections and generalizations such as "Have you ever worked on a question like this before?" deepen the understanding and appreciation for the problem at hand as well as the subject overall. This type of questioning allows the teacher to support students to link prior knowledge with new problems and, thus, be actively involved in the construction of their knowledge. This approach is in line with constructivist educational theories, advocating students' discovery of their own mathematical understanding so as to engage them in active knowledge construction (Cobb, 1994).

Action research can be defined as teacher inquiry into classroom practice with a purpose of improving classroom practice and seeking improved understanding of educational situations that arise (Feldman & Minstrell, 2000). It can be used as a self-assessment tool that assists teachers in identifying the needs, assessing the development processes and evaluating the

results of the changes they design and implement (Johnson, 1993). My interest in the impact of questioning came about early on in my teaching practice. I recognized the need for a better use of questioning in the mathematics classroom from both observing colleagues and evaluating my own practice. The mathematics curriculum in Ireland has undergone many changes in the last number of years and I recognized questioning as an important tool in teaching the new Project Maths syllabus.

Project Maths has been introduced as a new Maths syllabus for second-level schools in Ireland. It aims to improve levels of engagement among students and achievement overall by placing more emphasis on conceptual understanding as well as practical and contextualized application, rather than the previous practice of rote learning (National Council of Curriculum and Assessment, 2012; O'Mahoney & Heinz, 2016).

After much reflection and evaluation, I decided that the focus of my questioning should be heavily linked with engaging students in critical thinking, specifically justifications and generalizations. Research in mathematics in the last decade has consistently called for the "need to promote student's learning that goes far beyond the acquisition of mathematical knowledge, but including also the development of mathematical capabilities such as problem solving, reasoning and communication" (Ponte, 2011 cited in Menezes et al., 2012, p.357). I recognized this need in the mathematics classroom and decided to act upon it by engaging in this study.

Methodology

This study was undertaken with a mixed ability transition year group (13-14 year olds) of 12 male students in a second-level single sex boys school in Ireland. At the time of undertaking this study, I completed my final school placement block as a student teacher in this school, and I taught this transition year[2] group twice a week.

During my classes in advance of this particular study, I gradually introduced the transition year group to questioning and discussion as a means to studying problems. It was something they were not accustomed to in the mathematics classroom previously. As part of each lesson, I encouraged students to talk about, discuss, and debate their solutions or thoughts about each task. I used the 'Socratic Model of Questioning' and, specifically, the questions outlined in the literature review (Cox & Griffith, 2007). I noticed that I used the 'why?' question most often.

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[2] Transition Year is a one-year school programme that can be taken in the year after the Junior Certificate in Ireland. Students are approx. 15-16 years old. Depending on school population and funding it may not be available in some schools or compulsory in others. It is designed as a bridge between junior and senior cycle programmes and schools devise their own programmes.

During my ninth week teaching the transition year class, I initiated my specific research task – The Tower Problem (Martino & Maher 1999), which asked students to:

1. Build as many towers 4 cubes tall as possible with cubes of two colors
2. Figure out how to convince others that they had built all possible towers combining the cubes of two colours (that there were no duplicates and that they had not omitted any options).

Each student was provided with the problem sheet – explaining the task as well as a bag of cubes to allow students to build their towers (a sufficient amount for the 16 different towers that could be built as well as many extra cubes were provided to allow students to build duplicates). Extra paper for note taking was also provided.

While students worked on this task, the following data were collected:

- a voice recording of the full class

- students' written work

- researcher's observations and reflection notes.

All voice recordings were transcribed verbatim. Data analysis focused systematically on the relationship between the use of teacher questioning and the resulting student justifications and generalizations. Socratic questions used by the teacher as well as student generalizations and justifications were noted and categorized (see tables 1 and 2).

The limitations of this study are evident in the small number of students that took part, the fact that the school setting is a single-sex male school, and the main criteria for answering the research question relies heavily on one specific task.

Results

Questions that stimulated student justification and generalization. It is clear from the voice recorded data that there was a strong relationship between the questions students were asked and their progression with building a solution and working towards a justification. The questions student 1 was asked allowed him to take ownership of his solution. He was then, after several further questions, able to show how he built the towers and to use that as a justification for his solution. His explanation needed work and he was aware of that by the end of his interaction with the teacher, and he was then left to concentrate on developing his explanation. When questioning student 2 it was evident that deeper thought was needed around the construction of his towers in order to solve the problem. Strategic questioning allowed him to reflect on his methods and focus on those to build the remainder of his solution. The conversation with student 3 shows again the importance of questioning. This student built 15 towers and believed he had a solution but when questioned on how he knew he had all the possible outcomes he re-considered and realized further work was needed.

The voice recorded data further shows a direct relationship between the questions students were asked and their extended efforts towards generalizing their justifications. When questioning student 4, it was clear that he was convinced that he had fully justified his solution. Further questioning engaged him in more critical thinking and motivated him to prove his solution for 3 towers. The transcript conversation with student 5 is particularly interesting. His solution of 2^4 was correct, but it was evident that, when questioned, his knowledge of this fundamental principle of counting formula was limited. Although 2^4 and 4^2 worked out the same for the number of combinations in this particular problem they would not for towers of a different height. Instead of correcting the student, strategic questioning put him on the path of discovering that for himself.

The extracts provided below serve to provide an authentic flavor or the student-teacher interactions and the use of different types of questions. Socratic questions formulated by the teacher to motivate students to keep trying, to generalize and to justify are highlighted in bold print.

Justification

Student 1: Have 17 but don't think I'm right, think I've an extra one.

Teacher: Do you? Can you find it?

Student 1: Yep. There.

Teacher: Where's that one?

Student 1: Oh it's there, no it's not, [pause] there it is.

Teacher: Do you think you have them all now?

Student 1: Yea [pause] think so.

Teacher: You've no more extras?

Student 1: No. Don't think so.

Teacher: **Ok, c'mon you have to be sure**.

Student: Yea I am sure, cos I have all the possible outcomes. I have one on top, one in the middle and then all the different outcomes.

Teacher: Right?

Student: Em.. [student pauses and studies his built towers]

Teacher: **What way could you explain it to someone to prove you definitely have all the outcomes?**

Student 1: Em.. [long pause] I started with them all green and then I put one in place for each of the greens, then I did the same with the blue [pause] and eh, I got all the ways of one of an odd colour in the four of them, you work out [pause] change up the different colours as many times as you can

Teacher: **Okay, so think about a way you can write that down. I think you're on to something there.**

Teacher: **How would you describe your pattern?**

Student 2: What pattern?

Teacher: Your system of doing these.

Student 2: Em..I duno [student pauses and studies his built towers]

Teacher: **Would you describe it any way at all? Is it just a bit random?**

Student 2: No, like you always continue down from the simplest one here..[student demonstrates with his built towers] you get 8 here…colours are always touching.

Teacher: Okay, and how many do you have?

Student: 8..[counting] no, 13.

Teacher: **Do you think you have them all now?**

Student 2: No.

Teacher: How many do you think there are?

Student 2: I'd say there are 22 or 24 all together.

Teacher: You think?

Student 2: Yea about that.

Teacher: Okay, keep going.

Teacher: How many do you have?

Student 3: I have 15.

Teacher: And how many do you think there are in total?

Student 3: 15.

Teacher: Do you?

Student 3: Well I can do them like and see.

Teacher: **How do you know you haven't missed one or made one twice?**

Student 3: I don't.

Teacher: No?

Student 3: Well I'm pretty sure I haven't like.

Teacher: **Okay, well how about you take another look and I'll come back to you when you are sure.**

Generalization

Teacher: What was your system?

Student 4: Well start off 4 colours, 3 colours, 2 colours in each and then one. And that was my way.

Teacher: **What about 3 cubes tall?**

Student 4: [pause] Emm..Wouldn't be as much outcomes.

Teacher: **Why do you think that?**

Student 4: Cos there is less blocks and that would take out some.

Teacher: So how many outcomes would you reckon?

Student 4: It would be 9.

Teacher: You think?

Student 4: Yea, going by the same way.

Teacher: **Ok try it.**

Teacher: Why is it 2^4?

Student 5: Because 2 different colours and 4.

Teacher: **Where did your formula come from?**

Student 5: Just the numbers 2 and 4.

Teacher: How did you know to do that?

Student 5: Well you can put 2^4 or 4^2, same **answer 16 .**

Teacher: Ok well would it work for 3 towers?

Student 5: Emm..I duno you'd probably have to change it.

Teacher: How many outcomes do you think you'd get using that formula?

Student 5: 9.

Teacher: Think so?

Student 5: Yea probably.

Teacher: **Okay, try it**

Extent of use of Socratic Questioning. As part of the analysis of transcripts, all Socratic questions asked by the teacher were counted and categorized. Table 1 provides an overview of the number of Socratic questions used by the teacher by question category. It shows that the majority of teacher questions (86) served to encourage students to clarify their thinking. The voice recording also provided evidence that students were frequently challenged to test their assumptions (38 questions) and/or to provide evidence for their argument (32 questions). Questions encouraging students to consider alternative viewpoints or implications, and questions exploring questions were also used but to a lesser extent (between 9 and 20).

Table 1: The Type and Corresponding Amounts of Socratic Questions Used

Socratic Questioning Type	Examples of Most Common Questions Used
Getting students to clarify their thinking (approximately 86 questions of this type)	Why do you think that? Do you think you have them all? What was your system?
Challenging students about assumptions (approximately 38 questions of this type)	Are you sure you have them all? Do you think that's true for all towers? What about 5 towers tall / 3 towers tall?
Evidence as a basis for argument (approximately 32 questions of this type)	How could you convince someone you definitely have them all? Have you thought of a way you'd prove it?
Alternative viewpoints and perspectives (approximately 11 questions of this type)	What do you think about this [student name]? How about if you compare these two?
Implications and consequences (approximately 17 questions of this type)	Do you think they'd be convinced with your proof? Do you need to rethink that a little then?
Question the question (approximately 9 questions of this type)	Well, what do you think? Do you think they are the same?

Extent of student justifications and generalizations. The transcript and students' written work were analyzed to establish the number of students providing justifications and/or generalizations (see Table 2).

Table 2: Justifications and Generalizations (n=12)

Number of students providing justifications (Proof by cases, Staircase Proof, Proof by opposites)	Justifying by generalizing - using previous knowledge to prove this problem (2^n & Tree Diagrams)	Generalizing the justification (Applying justification to towers of different heights – 3 tall, 5 tall)
12	**13**	**8**

Justifications: In the class of 12, all students had, by the end of the class, justified their 16 towers, 4 tall with two colors. The most commonly used explanation of their solution was case by case – all towers with just one of the colors, all of the towers with just two of one of the colors, etc. Some students proved the problem by explaining their visualization of the towers as a stair pattern and others found a tower and found its opposite until they could find no more.

Insights from teacher reflections. The analysis of teacher reflections resulted in three core insights:
1. Student's urge to find a solution quickly

2. Difficulties with recognizing general applicability of formula
3. Socratic questioning modeled by the teacher encouraged peer assessment

Students' urge to find a solution quickly. Something that I had not anticipated was students' urge to find a solution to the problem before even arranging their combinations (building the towers). Students were trying to apply their somewhat limited knowledge of the fundamental principal of counting to the task by using the number of cubes tall (4) and the number of colors (2) – "Is it 4 × 4 × 4 × 4 × 2? m× n or something." I dealt with this by continuously telling students that the answer was up to them to decide and encouraged them to build the towers before making assumptions.

Difficulties with recognizing general applicability of formula. When students began to get the correct answer of 16 and I questioned them on how they knew they had them all and what was their system of finding all the combinations, all students were able to explain their methods – some explained proof by cases (towers of all one color, towers with 3 of one color, 2 of each color etc), proof by opposites (finding a combination and then finding its opposite until all combinations are exhausted) and others explained a staircase proof (where they arranged the towers side by side to form a diagonal for the different cases).

When I further questioned the students on the way in which they would choose to prove it, very few recognized their explanation as a type of proof. One student who had a solution as well as two justifications asked "Miss, are you going to give us the answer at the end or what's the story?" Some decided a tree diagram would be best, most tried to apply the fundamental principal of counting (2 ^ n) to the answer they got, but it was clear that none of them could clearly define or apply the fundamental principle of counting to begin with. When questioned on where the formula came from one student said "Text and Tests - the blue one." It was only when I introduced the generalisation questions such as: "Would it work for any towers? What about 3 tall? How many towers do you think you would get if I said to build them 5 tall?" that students recognized the general applicability of the formula.

Socratic questioning modelled by the teacher encouraged peer assessment. After all students had had sufficient time to articulate an answer and begin the process of justification the noise levels in the room began to rise. I found that after I had circulated around the room and asked the majority of students questions that caused them to reflect and reorganize their solutions, the students themselves began to critically assess each others' work. They all seemed to stick with their own original methods but became very interested in the ideas of their peers.

Justifying by generalizing and generalizations. All of the students made further attempts to prove their solution by applying their previously acquired knowledge of probability. The majority recognized the fundamental principle of counting as it applied to this problem but had to then generalize that further to ensure it would work for towers of any height. Many students also used their squares or drew out a tree diagram to solidify their solutions. The figures show that there were 21 types of generalizations altogether, which demonstrates just how many different angles many students took to prove their problems.

Discussion

The purpose of this research study was to determine how I can use Socratic questions to enhance students' critical thinking, generalization and justification skills in my mathematics classroom.

Maher and Martino's (1999) observation that students do not naturally seek to build a proof or justify their findings was clear to see from the observation notes as well as the transcripts. Socratic questioning proved an important driving force in motivating students to continue to search for and critically assess their solutions. Students were not accustomed to this type of continued follow-up questioning in their typical mathematics classes and neither was I, their teacher. The data clearly demonstrates that students' learning has been significantly deepened through the use of Socratic questioning which challenged them to think critically, experiment, justify and generalize. This active engagement opened up many opportunities for constructivism in mathematics – students' discovering their own mathematics (Cobb, 1994).

The findings from the state exams over the last number of years with regards to higher order skills (Jeffes et al., 2012) have evidenced students' urge to apply formulas without critical thought. Students in this study showed inexperience with the communication of mathematics and a lack of confidence in their solutions. The analysis has shown that students were generally used to, and expecting, one answer only problems; despite the various valid justifications and generalizations worked out by themselves, they still assumed that there existed one 'best solution' to the problem.

Overall the findings show just how central classroom questioning is in encouraging and supporting students to justify and generalize in mathematics. In a mixed ability class of twelve students, every student arrived at, and justified, the correct solution, thirteen further justifications through generalizations were made as well as eight solid justifications for towers of all heights (see Table 2).

I began this action research with concerns about my use of questioning. I not only studied the different types of questions but also the outcomes I wanted to achieve as a result of them. I found that students lacked practice in justifying and generalizing their solutions in mathematics. The reliance on the textbook and convergent one answer thinking was evident, and from the literature, I was aware that an appropriate way of enhancing students' skills in these areas was through questioning. Extensive reflection and evaluation made me realise the importance of listening to students and of clarifying their thinking before constructing questions. The 'Socratic Model of Questioning' proved an important tool in self assessing and guiding my use of questioning throughout my teaching practice.

Despite the limitations of the study, I believe the findings demonstrate a strong relationship between the use of Socratic questioning and students' effort and ability to engage in justifications and generalizations of solutions. The importance of careful monitoring of

students' progress, knowing when to probe and when to step away is evident from the qualitative data provided in the excerpts.

The central focus of action research is the cycle of self-evaluation and learning. Before the implementation, I was nervous and unsure about how I was going to handle the mixed ability in this context, how students would react to the problem, and if I would be able to remember all the questions I wanted to ask. I was, however, surprised very early on about how closely the progression of the class matched the literature that I had reviewed beforehand. Although I had a list of prepared questions with me, I did not need to look at them during the class. My research and preparation gave me the confidence to listen to my students, assess their progress and question accordingly.

Conclusion

This research project has given me great hope for my career in teaching mathematics. If students can achieve this level of critical thinking and create that many justifications and generalizations as a result of the use of Socratic Questioning on one task, then what could they achieve over a year? The findings of this study have encouraged me even more to focus on and practice Socratic Questioning to enhance my students' critical thinking, generalization and justification skills in the mathematics classroom. Now, more than ever, with the introduction of the new Project Mathematics syllabus, it is of paramount importance that, as a teacher, I enhance students' critical thinking, justification and generalization skills. It is clear that the questioning strategies used in this study have the power to do just that.

About the Authors

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EFFECTIVE MATHEMATICS INSTRUCTION FOR NATIVE AMERICAN ELEMENTARY STUDENTS: STRATEGIES FOR USING MANIPULATIVES

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Abstract Statistics from the National Center for Education Statistics (NCES, 2016) show that Native American students have high dropout rates and are outperformed by other racial groups on state assessments. Teachers of Native American students strive to teach to the best of their abilities, but may find themselves using traditional teaching practices rather than culturally appropriate practices for Native American students. The purpose of this mixed methods study was to determine the impact of culturally appropriate mathematics instruction with manipulatives on Native American students' engagement, achievement, and feelings about math and manipulatives.   During this mixed methods study, a class of 10 Native American fourth graders participated in lessons taught using traditional instructional practices, and research-based, culturally appropriate lessons involving the use of manipulatives. Qualitative and quantitative data was collected to compare the effects of culturally appropriate teaching methods and traditional teaching methods with manipulatives. Data suggested that teaching math in a culturally appropriate manner with manipulatives positively impacts students' achievement and increases their use of manipulatives, but has little impact on the overall engagement of students or students' feelings about mathematics. Based on data collected during this study, teachers of Native American students should revisit their current instructional approaches to ensure they are teaching in a culturally appropriate manner and correctly utilizing learning tools, such as manipulatives, to promote achievement.

Keywords: teacher action research, Culturally appropriate practices, manipulatives, achievement, engagement, Native American students

Introduction

Statistics from the National Center for Education Statistics (NCES, 2016) show that Native American students have high dropout rates and are outperformed by other racial groups on state assessments. In light of these statistics, it is clear that traditional mathematics

instruction has been ineffective in Native American student populations. Prior research revealed that Native American students learn best in cooperative learning environments participating in hands-on activities (Jacobs, 2013). Manipulatives in math instruction provide a means for hands-on activities. However, manipulatives can become more of a problem than a solution in the classroom if not utilized in a culturally appropriate manner. The purpose of this action research study is to determine the impact of culturally appropriate mathematics instruction with manipulatives on Native American students' engagement, achievement, and feelings about mathematics and manipulatives. The following research questions guide this study:

1. Does implementing research-based and culturally appropriate manipulatives instruction positively impact Native American students' engagement and achievement?
2. What are Native American students' perceptions of math and using manipulatives in math class?

With so much at stake for Native American students, it is important for teachers to adapt their teaching, perhaps by adopting culturally appropriate teaching practices, including the appropriate use of manipulatives.

Literature Review

Culturally appropriate teaching has been a hot topic in educational circles for several years now. Teachers have been made aware that they must strive to teach their diverse student populations equitably, not just equally. However, most research regarding culturally appropriate teaching practices is focused on African American and Hispanic students, with little research pertaining to Native American students. Manipulatives, their effectiveness, and how to appropriately utilize them in instruction has been studied at some length, but not in the context of the Native American classroom.

Native American Students. There are Native American students who are successful in school and life, and come from nurturing, stable homes. However, Native American students are among the poorest of American students and get academically out-performed by students of other races, particularly White and Asian students (NCES, 2016). Rittle-Johnson, Fyfe, Hofer, & Farran, (2016) found that early math literacy is crucial in the development of mathematics skills, and that students from economically disadvantaged homes came to school with very little mathematics knowledge creating an early achievement gap. Most Native American students come from economically disadvantaged homes, meaning that they come to school with few mathematics skills and need effective instruction in order to close the achievement gap.

Native American Perspectives and Culturally Appropriate Instruction. Traditional methods of mathematics instruction may not be culturally appropriate for Native American students. Jacobs (2013) wrote, "…although Indigenous mathematics knowledge paths are seldom considered, mathematics was highly developed in ancient Indigenous cultures throughout the world" (p. 158). Many teachers are of European descent and may not realize that the manner in which they teach is geared toward "mainstream" Americans: White, middle-class, and male. Teachers of Native American students need to instruct in a way that speaks to Native American perspectives and cultural values.

In Native American culture, everything is its own being. This includes people and animals as beings, but also includes natural elements such as air, water, and earth. Jacobs (2013) challenged teachers to take a Native American perspective when looking at mathematics and numbers; he wrote, "…[Think] of math not as static, but as always changing. Numbers are beings in constant change. To play with the possibilities of this change through mathematical operations is to look into the most basic aspect of relationships" (p. 164). Within the Native American view of mathematics, numbers are beings that relate to each other, and people relate to the numbers by manipulating them through mathematical operations.

With respect to all beings, Native American children are less accustomed to mainstream American perspectives, such as working hard to achieve in a competitive atmosphere. A Native American student is more likely to celebrate a being as it is, rather than what the being has done in terms of achievement. Therefore, a classroom structure that is highly competitive should be replaced with one that is highly collaborative. "Cooperation rather than Competition" is one of Hankes' (1998) principles for teaching Native American students, in which students work together to solve problems, rather than try to outdo each other as they would in a competitive setting.

Additionally, Hankes (1998) and Jacobs (2013) both found that Native American students respond to contextual, hands-on mathematics instruction. Jacobs (2013) stated, "Without context, knowledge is empty" (p. 161). Students must have relevant contexts with which to visualize the "beings" of numbers operating, and be provided with hands-on ways to manipulate these beings while solving math problems. Hankes' principles support the idea of collaborative, relevant, hands-on mathematics instruction in the Native American classroom, particularly by reframing problem solving as sense-making and integrating the students' lived experiences. Additionally, Jacobs (2013) discovered through his research evidence of the effectiveness of collaborative, hands-on instruction for Native American students.

The Importance of Using Manipulatives. Boggan, Harper, and Whitmire (2010) defined manipulatives as physical objects that can be used as teaching tools to engage students in the hands-on learning of mathematical concepts. Educational research indicates that the most valuable learning happens when students construct their own understanding of mathematical concepts, which can often take place by giving students opportunities to use manipulatives. Research by Carbonneau, Marley, and Selig (2012) found that using manipulatives in mathematics instruction produces a small to medium-sized effect on students' achievement, when compared to instruction that used only abstract symbols.

According to the constructivist learning theory, explained by Piaget, students build understanding upon experiences. Mudaly and Naidoo (2015) wrote about the Concrete, Representational, and Abstract (CRA) model of teaching, which is founded upon constructivist views, and its relation to the use of manipulatives in mathematics instruction. Within the CRA model, students move from concrete understandings, to representational reasoning, to abstract, conceptual knowledge. Manipulatives serve as the

foundational piece of concrete understandings, from which students can construct representational and abstract mathematical knowledge. The National Council of Supervisors of Mathematics (NCSM, 2014) also drew parallels from the constructivist theory of learning to the use of manipulatives. The NCSM (2014) stated that because of the experiential nature of the use of manipulatives, students are able to build mathematical knowledge from the use of manipulatives, so manipulatives should be used in mathematics instruction.

Correct use of Manipulatives. Van de Walle, Karp, Lovin, and Bay-Williams (2014) asserted that the most widespread misuse of manipulatives is done by teachers first, not students. Van de Walle, et al. contended that student misuse could be prevented by allowing students to have free time with the manipulatives before using them for problem solving, and by correcting manipulative misuse of the teacher. One example of a teacher's misuse occurs when a teacher tells students to "do as I do" with a manipulative. This merely teaches students a rote mathematical procedure. Van de Walle, et al. (2014) stated, "A rote procedure with a manipulative is just that - a rote procedure" (p. 25). Teachers must be challenged to relinquish some control of the use of manipulatives, even going so far as to let students choose which manipulatives to use to solve a problem.

Providing students with appropriate choices of manipulatives is important. Carbonneau, et al. (2012) found that perceptually rich manipulatives were most engaging. Lehmann (2015) offered a list of perceptually rich manipulatives including beans, counters, blocks, toys, and even simple objects like erasers. Larkin (2016) discovered that simply turning students loose with a manipulative is ineffective, and that educators must first be aware of a student's developmental abilities before unleashing them on a manipulative with the expectation that the student will have success with a mathematical concept just because a manipulative is present. Overall, Larkin found that students established connections between objects and mathematical concepts best when their use of a chosen, perceptually rich manipulative was scaffolded.

Culturally appropriate mathematics instruction that promotes collaboration and hands-on experiences is vitally important for the success of Native American students, most of which come to school educationally disadvantaged. Manipulatives, if used correctly, can be a culturally appropriate element to include in the mathematics classroom. Some strategies for correctly implementing manipulatives are identifying students' developmental abilities before beginning instruction with manipulatives, offering students time to choose from and play with a variety of perceptually rich manipulatives, scaffolding the use of student-selected manipulatives without teaching rote procedures, and encouraging collaborative problem solving of contextually relevant problems with manipulatives.

Methodology

Site and Sample. This action research took place at a small public school on a Native American Reservation in a Midwestern state. The school has approximately 185 students enrolled K-12, with 24% of students on Individualized Education Programs (IEP). Additionally, the school district has been identified as a Priority school by

the state Department of Education, due to underperforming test scores, poor attendance, and a variety of other school factors. One hundred percent of students attending the school receive free lunch and breakfast, indicating that many students have limited monetary resources.

Using convenience sampling, fourth grade students were the potential participants of this action research. The fourth grade class consisted of 11 students. One of the students was not a participant in the action research because the student gets pulled for special education services during most of the mathematics class period. The class had three students who consistently perform at grade level on a variety of assessments, including the Smarter Balanced assessment. The other seven students fall into strategic and intensive categories according to the Response to Intervention model (RTI) and defined by Aimsweb and the Standardized Test for the Assessment of Reading (STAR) Math assessments.

Based on teacher observations preceding the study, most of the 4th grade students became distracted or disengaged during math class. The high-achieving students found themselves waiting on the low-achieving students. The low-achieving students exhibited fixed mindset behaviors, in which they often disengaged from the learning process as soon as a task became difficult. The disengaged characteristics of the students, as well as the variety in achievement levels, made the students of the fourth grade class ideal potential participants to measure the effectiveness of culturally appropriate manipulatives instruction on student engagement and achievement.

Procedures. Qualitative and quantitative data were collected during this mixed methods action research study. Author 1 had a dual role in this action research as both the mathematics teacher and the researcher. As the teacher, lessons were strategically planned and delivered, and learning experiences with manipulatives were facilitated. As the researcher, qualitative and quantitative data were collected and analyzed it in order to answer the research questions.

As the researcher and teacher, author 1 recognized that the motivation of this study was to implement culturally appropriate practices for utilizing manipulatives with Native American students at the elementary level and to measure the effectiveness of those practices. Based on the exploratory nature of this study, conclusions were drawn solely on the data collected throughout the study.

Ethical Considerations. In order to conduct this action research ethically, permissions were gathered from all necessary parties including the Institutional Review Board (IRB), school principal, parents/guardians, and participants. Parents and participants were made aware that participation was voluntary, no penalty would be given for not participating and no incentives would be given for participating, withdrawal from the study was an option at any time, identifying information would be kept confidential, and that every measure would be taken to make sure that all aspects of the action research adhered to the Family Education Rights and Privacy Act (FERPA).

Data Collection. This action research study consisted of two phases and was conducted over approximately four weeks in February and March 2018 with ten fourth grade participants. Throughout this study, participants were asked to take surveys, engage in class activities using manipulatives, complete worksheets, and take pretests and post-tests. The risks for participants over the four-week timeframe were minimal, no more than typical risks for students involved in standard classroom experiences. In order to protect students from typical classroom risks, such as embarrassment from getting a problem incorrect, students were held accountable for the high expectations and rules that have been set in place since the beginning of the school year. Adherence to these rules and expectations established a respectful and safe class atmosphere conducive to learning.

During phase one traditional teaching practices were utilized, and then during phase two culturally appropriate teaching practices were implemented. See Table 1 for a comparison of traditional and culturally appropriate practices used in these phases. Throughout each phase, both qualitative and quantitative data were collected to answer the research questions:

1. Does implementing research-based and culturally appropriate manipulatives instruction positively impact Native American students' engagement and achievement?
2. What are students' perceptions of mathematics and using manipulatives in mathematics class?

Table 1: Traditional Instructional Practice versus Culturally Appropriate Practice

Traditional Instructional Practice	Culturally Appropriate Practice
Competitive classroom	Cooperative classroom
Individual work	Collaborative work
Lecture and worksheet	Discussion and hands-on experiences
Choice of manipulative made by teacher	Choice of manipulative made by student
Use of manipulative determined by teacher	Use of manipulative determined by student
Mathematics problems that are contextually irrelevant to students' lives and experiences	Mathematics problems that are contextually relevant to students' lives and experiences

Qualitative data were collected by conducting a survey about students' feelings about math and manipulatives, and recording observations of participants' levels of engagement and comments during discussions in a journal. Quantitative data were gathered by scoring tests and assignments, as well as comparing grades from week to week.

During phase one, approximately two weeks, traditional teaching practices were utilized and data were collected in order to compare students' achievement, engagement, and feelings about mathematics and manipulatives to data collected when culturally appropriate practices were used. The lessons during this phase were teacher-led, with word problems that had no relevant context to the lives of participants, and had a competitive nature as students worked individually or in teacher-selected groups to complete their assignments quickly and accurately. The use of manipulatives during this phase reflected traditional teaching practices. When manipulatives were made available to participants specific, non-negotiable instructions were given as to which manipulative was used and how students used it. Additionally, manipulatives were only available as students worked individually to complete a worksheet. There was little discourse between students during this week. Discussions were done in a whole class setting with me asking all the questions and participants supplying answers directly back to me.

This phase included a re-teaching week. From experience, Author 1 hypothesized some re-teaching of the concept taught using traditional teaching practices would need to take place. Assignments were collected and scored but not used as data since they consisted mostly of unfinished assignments, and it would have been difficult to quantify what learning had occurred because of teaching practices and what learning had occurred simply because the participant was given more exposure to the concept.

During the second phase, approximately two weeks in length, research-based culturally appropriate practices for teaching Native American students with manipulatives were implemented. The data collection process during this phase was the same as the process in phase one. Participants could choose which manipulative to use and how to use it, they also worked in groups or partners playing games with manipulatives, discussing their findings, and trying out different manipulatives to model problems that were reflective of their experiences.

To conclude phase two, all data were analyzed to answer the research questions. An evaluation of participants' engagement was done in order to compare engagement during both phases. Observations recorded in the observation journal served as qualitative data to track the engagement of participants. These data were compared to the baseline data and analyzed to conclude whether or not the engagement levels of participants changed as culturally appropriate practices were implemented.

Student achievement was also evaluated. To evaluate achievement, quantitative data from pretests and post-tests as well as assignments and grades were compared. Growth data between pretests and post-tests from both phases were compared. Achievement data were compared cumulatively to determine the impact of culturally appropriate teaching practices and research-based manipulatives instruction.

To re-evaluate the perceptions students held of math and manipulatives in math class, participants were asked to retake the survey they took in phase one. The two surveys were compared to see if participants' perceptions changed. These qualitative survey data were analyzed to determine in what ways the perceptions of participants changed.

Results

To measure engagement, qualitative data in the form of an observation journal were collected and reviewed to find themes or reoccurring behaviors among participants during the two phases. Engagement was noted in the observation journal when all students were participating in a learning activity or discussion. Disengagement was noted when a misbehavior arose, a participant shut down, or a participant was very hesitant to engage in a learning activity or discussion.

Observational data revealed that when traditional practices were implemented there was twice as much disengagement than engagement. For example, participants demonstrated disengaged behaviors when working individually with a manipulative I chose in a manner I insisted upon. This traditional approach led to misbehavior, and at best participants simply performed rote procedures with little learning being accomplished.

On the other hand, observation data revealed that when culturally appropriate practices were implemented there was an equal amount of engaged and disengaged behaviors. Participants' engagement with their chosen manipulatives increased when working with a partner or small group, rather than individually, and there was an increase in participants' problem solving with manipulatives when the problems they solved were relevant to their experiences.

A major theme that emerged from the observational data was "choice." There was a correlation between the amount of choices, a culturally appropriate practice, and engagement. The more choices offered, the more participants engaged. Whether it was offering a participant a choice of who to work with, what manipulative to use, or how to use a manipulative, participants consistently had the most positive response to manipulatives and tasks when they were given choices. According to the data, there were five times more occurrences of participants using manipulatives when given a choice of which manipulative to use and how to use it. See Figure 1 for comparisons of the effects of traditional and culturally appropriate practices.
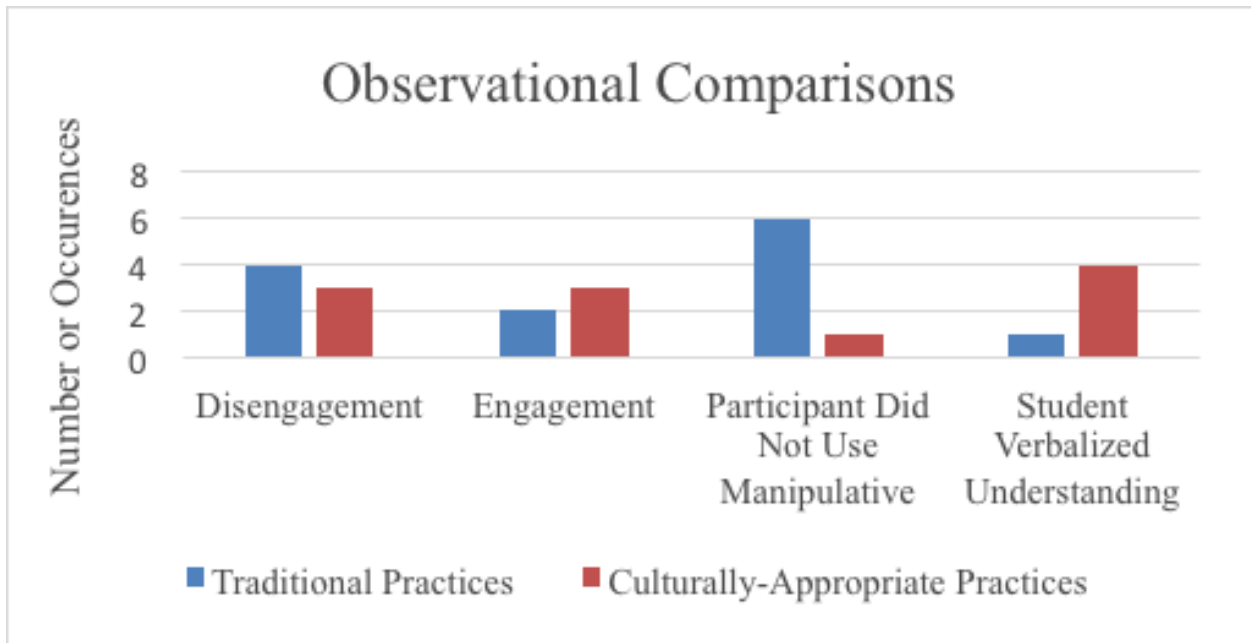
Figure 1. Observational Comparisons

Data to measure achievement were collected in the form of worksheets used to calculate weekly grades, growth between pretests and post-tests, and observational notes of instances where a participant was able to verbalize a mathematical understanding. When traditional practices were used, there was an adverse effect on participants' achievement measured by weekly grades and pretest and post-test comparisons. Thirty percent of participants' grades fell from the previous weekly grade, and fifty percent of participants scored fewer points on the post-test than pretest. On the other hand, when culturally appropriate instruction with manipulatives was used, participants saw achievement both on their weekly grades and on the post- test. Seventy percent of participants' grades improved and all participants scored more points on the post-test than the pretest. Additionally, data from the observation journal revealed that when culturally appropriate practices with manipulatives were implemented there were four times as many instances of participants verbalizing a mathematical understanding than when traditional practices were used.

Participants' perceptions of mathematics, manipulatives, and themselves as mathematicians changed very little when culturally appropriate manipulatives instruction was used. To measure the perceptions of participants, results of an anonymous survey were reviewed. The survey, taken at the beginning and end of the study, was three questions in length and required participants to circle a response that was most true of themselves. One survey question asked participants if and how much they liked mathematics. The answers to that question did not change from the start of the study to the end. Despite different teaching techniques and varying levels of engagement and achievement, there was no difference in how much participants liked mathematics.

A question regarding how good or bad participants thought they were at mathematics varied little from the beginning to the end of the study. One of the largest differences was seen in the category of participants who felt they were "math masters" as opposed to being "good at math," "okay at math," or "really bad at math." At the beginning of the study forty percent of participants felt that they were "math masters." At the end only ten percent did. However, the total percentage of participants who felt they were either "good at math," or "math masters" varied only slightly, with only five percent less feeling they were "good at math" or "math masters" at the end of the study.

Discussion

There are several notable findings from the data analysis. First, findings regarding how culturally appropriate practices affect the engagement levels of participants are somewhat inconclusive. The observational notes made regarding engagement did not differ significantly when culturally appropriate practices were implemented. However, it was made clear by the data gleaned from observational notes that when culturally appropriate practices are used participants are more likely to engage in activities using manipulatives, especially when given choices regarding how they work with manipulatives.

Second, data indicate that participants achieve more when manipulatives are used in a math class that supports culturally appropriate instructional practices. For example, during phase one, fifty percent of participants' scores dropped from the pretest to the post-test, indicating that traditional practices had an adverse effect on achievement. When culturally appropriate practices were utilized and the teacher presented manipulatives in a proper manner, participants used manipulatives more often and completed more assignments resulting in higher achievement measured by grades and performance on the post-test. Data from grades and post-test scores revealed that using culturally appropriate practices with manipulatives increased achievement for seventy percent of participants, with thirty percent of participants maintaining their grades. Figure 2 compares grades of participants. As illustrated, sixty percent of participants achieved more when culturally appropriate practices with manipulatives were utilized, and no participants had a failing grade.
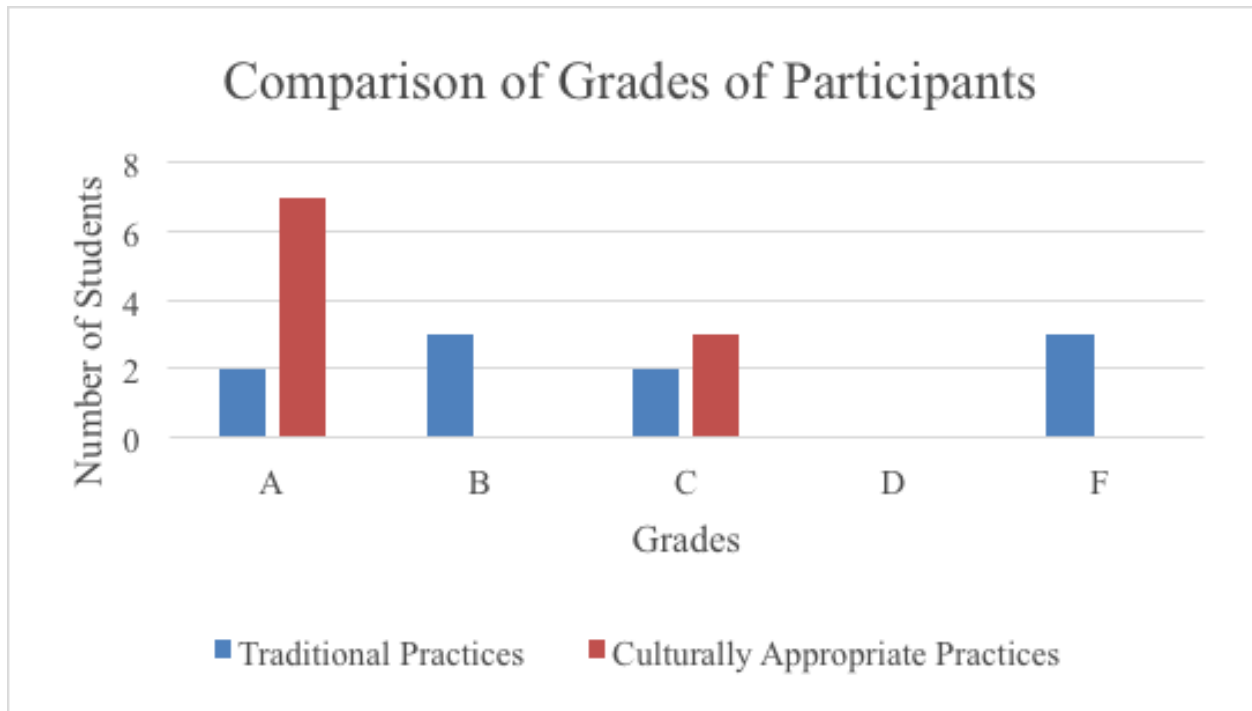
Figure 2. Comparison of Grades of Participants

Third, participants' perceptions of math and manipulatives did not significantly change when lessons were taught in a culturally appropriate manner with manipulatives. The survey data revealed that some students lost confidence in their mathematics abilities, going from "math masters" to just being "good at math." But, overall, more students felt like they were "good at math" or "math masters" after the week of culturally appropriate lessons was taught.

Implications

This study's purpose was to find out if using manipulatives in a research-based and culturally appropriate manner in a mathematics classroom serving Native American students affected students' achievement, engagement, and feelings toward math. The data collected throughout this study showed that students' achievement rose when manipulatives were used appropriately during lessons that were tailored to fit Native American culture. However, data indicated that engagement and feelings toward mathematics did not differ significantly when manipulatives were used using research-based best practices in a culturally appropriate manner. In order to increase achievement for Native American students, mathematics teachers of Native American students should evaluate their use of manipulatives and the structure of their lessons to ensure they are using manipulatives appropriately and creating lessons that are sensitive to Native American culture.

Understanding one's teaching materials and best practices for teaching students of varying cultures can be applied to any teacher. As this study illustrates, using best practices and culturally appropriate methods yields greater student achievement than traditional teaching

methods alone. To facilitate this, teachers should become familiar with research-based teaching strategies for their content areas and culturally appropriate teaching strategies based on their student population. This study was limited by the number of participants involved and the length of the study. A longer time with a larger group of participants may provide more comprehensive data from which to draw conclusions.

Conclusion

The focus of this study was to gauge the impact of culturally appropriate mathematics instruction with manipulatives on Native American students' engagement, achievement, and feelings about math and manipulatives. By implementing culturally appropriate practices and effective instruction with manipulatives, teachers of Native American students can increase achievement, even though students' engagement and feelings toward mathematics and manipulatives may not change. Native American students are a vulnerable population and educators who teach in a way that honors the culture of their students, and who wield teaching tools in accordance to research-based best practices, give their students a greater chance for learning and achieving.

About the Authors

Traci Stiegelmeier is originally from Ridgeview, South Dakota. In 2012, she graduated Summa Cum Laude from the University of Mary with degrees in Early Childhood Education, Elementary Education, and Special Education. After graduation, she spent three years teaching second grade and three more years teaching elementary math at a rural elementary school on a reservation. In 2018 she earned her Master's degree in Curriculum and Instruction from Black Hills State University. Currently, Mrs. Stiegelmeier is taking a break from her teaching career to stay at home to raise her son and help her husband, Levi Stiegelmeier, on their family farm. Email: traci_truax@hotmail.com

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