



Editorial from Małgorzata Marciniak, a Managing Editor

It has been year since I began my duties as a Managing Editor of the Mathematics Teaching Research Journal and I treasure every minute of it. The journal has been going through numerous transformations to match the digital standards of modern times. We have been working on our webpage and hoping that it will be updates soon. The current volume, V10 N2, of the Mathematics Teaching Research Journal

The summer edition of volume 10 contains articles about creative pedagogy, analytical approach to assessment, student research initiative, and a review of a popular mathematics book.

The article “Teaching Middle School Mathematics through Robotics Project-Based Learning” by B Falk and L. Columba discusses robotics project in the middle school mathematics classroom and outside. The authors interviewed two robotics program mentors and analyzed findings from their reports. As the final conclusion, the authors make a suggestion for increasing the efforts of investigating whether teaching the students robotics increases their learning in mathematics.

In their article “Methods of Mitigating the Effects of Stereotype Threat on Female Students’ Mathematics Performance in a High School Geometry Classroom” A. Chodnowsky and L. Columba uncover the lack of awareness of the gender threat among students and teachers. The authors performed three surveys in a 20-student classroom and create three hypotheses for their work: students are aware of the stereotype; students are not aware of the stereotype threat; students are not aware of the impact of the stereotype threat on their performance. In their conclusions they point out that the good intentions of the teacher are the crucial factor in influencing the performance of the female students regardless the awareness of the stereotype.

J. A. Telese in his article “The Relationship Between Assessment Practices and Hispanic and White Eighth Grade Students’ Mathematics Achievement: An Analysis of 2013 NAEP Data” examined data from the 2013 NAEP eighth grade mathematics assessment. He performed multiple regression analyses to examine the relationship between the frequency of use various assessment strategies and student mathematics achievement. The results of his work show that Hispanic students’ mathematics performance was at a lower level than non-Hispanic (White) students. What is the most interesting in his article indicates that both groups of students had lower mean composite scores as the reported frequency of assessment increased. The findings of the article suggest that formative assessment strategies have a negative relationship with the Nation’s eighth



grade mathematics students. This result calls for additional reflections on the amount of the assessment and its alignment with other teaching tools.

This volume continues the recent tradition and contains a book review. The book “Prime Obsession: Bernhard Riemann and the Greatest Unsolved Problem in Mathematics” written by John Derbyshire was reviewed by a veteran of popular mathematics book reading, Roy Berglund. Hopefully the tradition will continue in further volumes since the amount of mathematics books on the market is currently overwhelming but only some are truly amazing.

The article “Creating Undergraduate Research Opportunities Through Interdisciplinary and Intercollegiate Collaboration” by M. Powell presents an Illinois initiative, The Intercollegiate Biomathematics Alliance that brings together students and faculty in their efforts of shared research projects in biomathematics. One of their major ways of developing undergraduate research is through a research workshop. Projects are initiated by faculty inviting students to collaborate with them, and students are provided the opportunity to present their work at a national conference and publish in a peer-reviewed journal. The article describes the details of the research workshop and give insight into contributions to both the success and challenges of successful research with undergraduate students.

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Teaching Middle School Mathematics through Robotics Project-Based Learning

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***Abstract:** This paper discusses the use of robotics project-based learning in the middle school mathematics classroom and the mathematics that is currently being taught in robotics programs both in the classroom and outside of the classroom. Two robotics program mentors were interviewed about their experience with three different robotics' programs, one in-school and two after-school programs. The similarities between the concepts and teaching methods are discussed in the two different robotics programs. The mathematics concepts that the mentors developed in their respective programs are provided. Finally, suggestions are made for further research in the areas of student academic achievement in robotics project-based learning programs.*

INTRODUCTION

In recent years there has been an increase in the use of robotics project-based learning in schools through a variety of programs such as, VEX Robotics, FIRST (For the Inspiration and Recognition of Science and Technology) Robotics and LEGO® MINDSTORMS® (Bartholomew & Furse, 2015). In the VEX Robotics program, middle level and high school students are given a yearly challenge, and must design, build, program, and drive a robot to complete the challenge as best as they can. The FIRST Robotics program includes teams of middle and high school-aged students who are challenged to design, build, and program a robot to play a floor game against other teams' creations. LEGO® MINDSTORMS® is a hardware software platform produced by Lego for the development of programmable robots based on Lego building blocks. The reason for the increase in robotics instruction can be attributed to schools' and private companies' desires

to increase the number of students who can solve technical problems and create technological advancements that improves lives (Robinson, 2014).

Robotics can be used to teach a wide assortment of skills and concepts found in Science, Technology, Engineering and Mathematics (STEM) fields. Some topics in mathematics can be more easily taught through robotics project-based learning than others. Although teachers may want to implement robotics project-based learning in their classrooms they may not be comfortable with the technology or the mathematics required (Cejka, Rogers & Portsmore, 2006). Mathematics teachers may have difficulty determining which topics can be easily and efficiently taught using robotics project-based learning. Teachers' discomfort with robotics and the difficulty in creating lessons around robotics may discourage teachers from using robotics project-based learning in their classrooms. In addition, the unavailability of funds to cover the cost of purchasing robots can be a limiting factor in some classrooms. Fortunately, many robotics programs that are not run with the intention of teaching mathematics concepts do end up teaching mathematics topics because knowledge of a mathematics theorem is required to complete the intended goal of the robotics program.

The purpose of this research study was to explore how teachers in robotics programs integrated mathematics concepts into their instruction. Two research questions guided the study:

1. What mathematics topics and/or concepts do teachers develop in their robotics programs?
2. How do robotics teachers integrate mathematics in the classroom?

REVIEW OF THE LITERATURE

Project-Based Learning (PBL) is a constructivist teaching strategy in which students collaborate with their peers to complete a project to allow the students to use and reflect on their learning (Kizkapan & Bektas, 2016). Constructivism is an approach that expects students to assemble and interpret new knowledge, instead of memorizing (Kizkapan & Bektas, 2016). So by conducting the investigations, having the conversations or completing the activities necessary to complete PBL a student is learning by building on their current knowledge and adding new knowledge (Grant, 2002). PBL can increase students' interests in STEM fields because students are engaged in solving real world authentic problems, as well as working with others and creating real solutions (Laboy-Rush, 2011). The explorations in PBL begin with the end product in mind, and as such use a production model, and therefore mirror the real world production model (Remijan, 2016). In addition, PBL improves students' meta-cognitive skills so that students are able to make successful plans and evaluate their solutions. Also, PBL creates a more equitable learning environment and so contributes to students' academic success (Kizkapan & Bektas, 2016).

When teachers implement Project-Based Learning in the mathematics classrooms the students' motivation often increases because the projects empower students, the projects are thought provoking to the students, and the students are invested in the results (Remijan, 2016). Studies on the impact of STEM PBL have shown that lessons including STEM PBL increase students' positive attitude toward STEM fields and improve students' mathematic academic achievement. Han, Rosli, Capraro and R. Capraro (2016) found that PBL improved students' mathematics scores in the areas of algebra, geometry and probability.

Robotics lessons can be implemented at all grade levels and used to teach a variety of STEM related topics. For example, robotics can be used to teach students about functions by asking students to program the robotics to travel in the pattern designated by distance-time graphs, the students are only able to program robots to meet the requirements of the graphs that are functions (Fernandes, Ferme & Oliveira, 2006). The Center for Engineering Education Outreach at Tufts University has worked to bring robotics into K-5 classrooms by training teachers, providing classroom support and developing robotics curricula for all elementary grade levels (Cejka, Rogers & Portsmore, 2006). Robotics programs help students meet STEM objectives and develop critical thinking and "soft skills" (Bartholomew & Furse, 2015). There are some challenges with implementing robotics curricula and robotics programs, including teacher ability, limited technological resources and interpersonal struggles (Bartholomew & Furse, 2015).

For this paper the researcher interviewed two women who ran two extracurricular robotics programs and one in school robotics program. The purpose of the interviews was to learn more about how these women used and taught mathematics in their robotics programs. (See Appendix A) The mentors were both involved in the FIRST LEGO League (FLL) robotics program and both had a background in STEM fields. The women will hereafter be referred to as mentors because mentor is FLL's official title for its adult volunteers and because mentor accurately describes both women despite their differing STEM education backgrounds and experience. One of the mentors is a teacher, and also teaches classes involving robotics. Before becoming a teacher this mentor worked in computer science. The other mentor home schools her children, has studied mathematics and engineering and has experience applying those concepts to real world problems through her work flying helicopters. The FLL robotics programs consisted mostly of students in middle school. The in-school robotics program consisted of sixth and seventh grade students.

RESULTS

All three of the robotics programs, both FLL programs and the in-school program, developed mathematics concepts. The mentors talked about a variety of mathematics concepts, all of which were taught in context of solving momentum problems (See Table 1). The most common examples given by the mentors involved momentum and forces. In the FLL program the students are given a set of challenges and a time limit, the students choose which challenges to complete in order to get the most points. The mentors described how students learned about momentum while

trying to lower an arm to drag something and having the arm bounce, or about forces when the robot ran into an object with too much or not enough force. Although the students did not use momentum formulas they were using expressions, numerical constants, symbolic names, and mathematical operations, and functions in a formula according to one mentor.

The in-school robotics program used spherical robots (mobile ball-shaped robots with a spherical external shape) and the students applied momentum concepts as well, when they had to make the spherical robot stop rolling. The students use a C-based programming language for middle school and they write code for the robot to go straight, stop, change color along the way, and make ninety-degree turns. Both mentors also mentioned using angles. The mentor of the in-school program gave an example of using protractors to measure angles and help students determine how much their robot needed to turn. This discussion led some students to ask if they could use decimals to get a more accurate ninety degree turn from the robot.

Speed and rotation were also discussed by both mentors as mathematics concepts that their students explored while building and programming robots. One mentor talked about how she had asked students to consider different ways to measure a distance, including using a wheel and rotations. The other mentor gave an example of using rulers to measure rotations but added that usually the students experiment and figure out rotations and measurements on their own. The mentors both discussed how visualizing and examining mathematics concepts like angles gave the students a better understanding and made the concept more concrete for the students. The curriculum engaged students meaningfully in STEM concepts with the mathematics instruction integrated as the need arose from the students. One teacher stated, "...[the mathematics] it sort of takes it from being abstract something out of a textbook that they [students] actually get to put to work" and "they [students] use math that is the important part." In the after school programs the students are not formally assessed on their projects. However, the students compete in regional competitions and if they score high enough the students participate in state level competitions. (See <https://www.vexrobotics.com/vexiq/education/iq-curriculum> for example lesson plans and complete units in robotics for middle level students.)

In the FIRST LEGO League (FLL) robotics program the teams are assessed in the areas of Robot, Research Project, and Teamwork. (See <https://www.first-lego-league.org/en/general/evaluation.html> for additional information.)

Table 1

Mathematics concepts taught in the context of robotics momentum problems.

Mathematics concept	Number of mentors who taught the concept
Acceleration	1
Angles/degree measure	2
Deceleration	1
Decimals	1
Force	2
Logic	1
Measurement	2
Momentum	2
Percentages	1
Rotation	2
Speed	2

Both mentors taught student-driven robotics programs. This aligns with FLL's values and both mentors said that the students have been successful with this approach. Since the programs are mostly student-driven the mathematics the students learn and explore is also student-driven. As a result, there was minimal explicit teaching of mathematics concepts; instead mathematics concepts were addressed when the students encountered the concepts on their own. Also, both mentors used questioning techniques to help students discover their own solutions and the mathematics concepts behind the solutions. Both mentors talked about asking students' questions like "What happened?" "What was supposed to happen?" and "How can we change something in order to make that happen?" While the mentors both reported that using the mathematics concepts to solve real problems helps cement the concept for the student, they were not sure if using mathematics in the context of robotics increased students interest in mathematics. One mentor said that she was not sure if her students even realized that they were doing mathematics.

DISCUSSION AND FUTURE RESEARCH

Implementing robotics lessons into a mathematics curriculum may be challenging for some classrooms because of the cost of the robots. The results from this study of three robotics programs, recommend designing lessons around concepts that students in robotics programs are encountering naturally. By creating robotics PBL lessons around concepts such as speed, momentum and angles, mathematics teachers can engage students in real problems that the students enjoy solving.

An area for further study is how robotics PBL impacts students academically in mathematics. Research should be done to determine if teaching students' robotics does in fact increase students over all mathematics achievement abilities. Also learning more about students' attitudes towards mathematics taught through robotics would be another area for future research.

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Methods of Mitigating the Effects of Stereotype Threat on Female Students' Mathematics Performance in a High School Geometry Classroom

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Abstract: *This action research study looked at stereotype threat in a single high school geometry classroom. The study examined three methods of mitigating the effects of stereotype threat, and whether those methods were being implemented in the classroom. Stereotype threat has been found to have an effect on female students' mathematics performance. This study sought to determine if the students and teacher were aware of the stereotype by surveying the class, and if the teacher did anything to lessen the effects of stereotype threat that may be happening in his classroom. The results found that while the teacher and the majority of the students were not aware of the stereotype or stereotype threat, that positive strategies used by an effective teacher can still be methods for lessening the effects of stereotype threat even when that is not the motivation behind their implementation.*

Keywords: stereotype threat, stereotype, mathematics performance

INTRODUCTION

Stereotype threat is a phenomenon which occurs when negative stereotypes about a group to which an individual belongs can have an impact on their performance and goals in a certain field (Quinn, Steele, & Spencer, 1999). This is especially prevalent in academia: if a student is aware of a stigma of a minority group of which they are a member, they may be more likely to judge all academic situations on whether or not the stereotype may be confirmed by their actions (Quinn et al, 1999). This can cause the student to perform worse on assessments and examinations, thereby seeming to confirm the negative stereotype about their group.

There has been a widely established stereotype that women are less proficient at mathematics than their male classmates. For example, this stereotype has been reinforced by studies which determined that when male and female students who perform equally on assessments that can be considered easy or on target for them are assessed at a more advanced level, male students tend to outperform female students (Quinn et al, 1999). Hypotheses about the cause of these performance disparities suggest that male students perform better than female students in mathematics as a result of inherent genetic differences, thinking that males are genetically predisposed to have stronger mathematics ability (Benbow & Stanley, 1980).

REVIEW OF THE LITERATURE

In a 1999 study, researchers Spencer, Steele, and Quinn argued that gender differences in mathematics were the result of stereotype threat, where female students' mathematics performance was directly affected by anxiety as a result of the widely perpetuated stereotype. Their research did confirm the hypothesis that stereotype threat can undermine women's mathematics performance. This anxiety can also have a direct correlation between stereotype threat and the concept of "math anxiety," where students have such fear of mathematics that they tend to feel anxious when confronted with math, and perform worse on mathematics assessments and examinations. (Carey et al, 2016.)

Thus, it is imperative for teachers who want to ensure the success of their own female students in mathematics to try to lessen the impact of stereotype threat in their classroom. Several methods of mitigating the effects of stereotype threat haven been studied, three of which are: priming positive images prior to an assessment (Aronson & McGlone, 2006), making students aware of stereotype threat (Johns, Marten, & Schmader, 2005), and creating an identity safe classroom (Cohn-Vargas & Steele, 2014).

Priming positive images prior to an assessment, or giving students positive ideas about the assessment and themselves, can look like a teacher saying to their students, "You are all capable of doing well on this test, I believe in you and your success." This strategy has been proven to lessen the effects of stereotype threat, because students are less likely to think about negative stereotypes about a group they are a part of, and instead perform to their potential (Aronson & McGlone, 2006). Teachers have a responsibility to their students to convey belief in them, and create a space where students can live up to their potential.

Another method of mitigating the effects of stereotype threat on female students' mathematics performance is making students aware of stereotype threat. If female students are aware of what stereotype threat is, they are less likely to be affected by stereotype threat because

this allows female students to separate any anxiety they may have as a result of this stereotype from their own abilities. (Johns et al, 2005).

A third strategy for combating the effects of stereotype threat examined in this study was creating an identity safe classroom. An identity safe classroom is one where all students feel like they can be themselves, regardless of outside expectations of them from their sexual orientation, gender, race, religion, or disabilities. To create an identity safe classroom, teachers should be mindful of differences between students, but still allow students to speak about what makes them unique relative to their peers. This strategy mitigates the effects of stereotype threat as it makes the students' identities part of their learning experience, rather than something that may limit potential to perform in class in some way. (Cohn-Vargas & Steele, 2014).

The hypotheses examined in this study were: students are aware of the stereotype, but not necessarily of stereotype threat and the impact it can have on female mathematics students; female students are more likely to be aware of the stereotype than male students; teachers are aware of stereotype threat, although they may not know strategies to mitigate its effects; even if a teacher is not necessarily addressing stereotype threat as a priority in their mathematics classroom, they will still be implementing at least one of the three strategies in the classroom because of the positive impact they can have on all students.

METHODS

The research conducted in this study was in the form of an action research study performed with students in a single class. The classroom was a grade-level geometry class at a large suburban high school in the northeastern United States. The classroom in question was chosen because of previous connections held by the researchers to the class, as well as the even split in gender.

The participants were 20 students ranging from 10th-11th grade. Nineteen of the students were Caucasian, and one was African American, and 10 of the students were female, and 10 of the students were male. Most of the students were from middle or upper-middle class backgrounds. None of the students were categorized as having a disability with an Individualized Education Plan or a Section 504 Plan. The teacher in the class was a white male teacher with over 20 years' experience teaching at the school where the study was conducted.

The study was conducted in the form of three surveys: a longer, initial survey (Appendix A.) issued to the students, an initial survey issued to the teacher (Appendix B.), and lastly a shorter, follow-up survey administered only to the students (Appendix C.). A few days after administering the first surveys to the teacher and the students, the researcher had a small discussion on stereotype threat with the teacher, then held a discussion on stereotype threat and the three ways to limit its

effects being studied with the students the following day, directly after which the researcher administered the final survey. The first survey was administered during the start of the mathematics class. The students were instructed to fill out the survey as honestly as possible, and assured that no one except the researchers would see their surveys, including their teachers, and that it would not affect their grades in any way. Simultaneously, a survey was administered to the teacher in the classroom that was similar, but not identical to the survey the students received. A few days after the survey was administered, the researcher discussed with the teacher what stereotype threat is, and the three ways to mitigate the effects being studied. Following this, the researcher presented students with the definition of stereotype threat, as well as made students aware that there is a false stereotype that female students do not perform as well in mathematics classes as male students, as many students were not aware of the stereotype according to the results of the original survey. The researcher then taught students the three ways of lessening the effects of stereotype threat, offering students an opportunity to ask questions about stereotype threat if they had any. Lastly, the researcher administered a short follow up survey to the students, which asked students only three questions.

RESULTS

The results of the study indicated that students in this school are mostly unaware of the stereotype about male students performing better at mathematics than female students, and so are logically less affected by stereotype threat. Figure 1 shows the results of the question: “Have you ever heard of the stereotype that male students are better at mathematics than female students?”

Percentage of Student Aware of Stereotype, by answers to the question: Have you ever heard of the stereotype that male students are better at mathematics than female students?

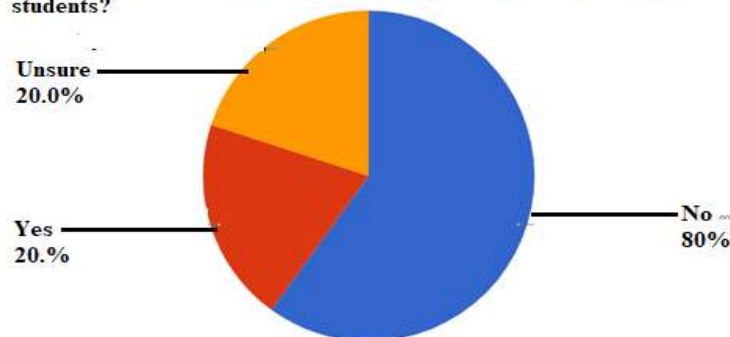


Figure 1. Students aware of stereotype threats.

The majority of the students 60% (12 students) said “No,” 20% (four students) said “Yes,” and 20% (four students) were unsure if they had ever heard the stereotype previously.

When comparing knowledge of the stereotype by gender, the results show that there was no difference between male and female students, and that exactly the same number of students of each gender knew and did not know about the stereotype (Figures 2 and 3).

Female Students Knowledge of Stereotype

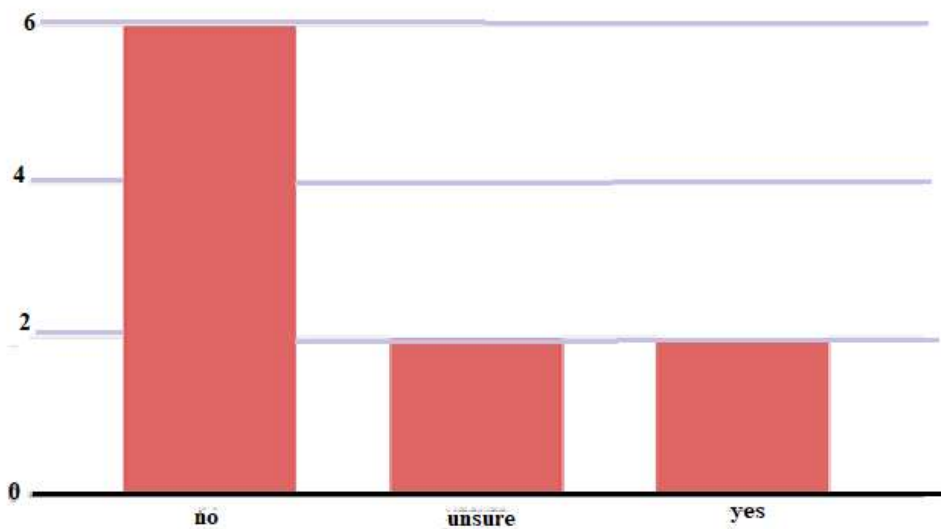


Figure 2. Female students aware of stereotype.

Male Students Knowledge of Stereotype

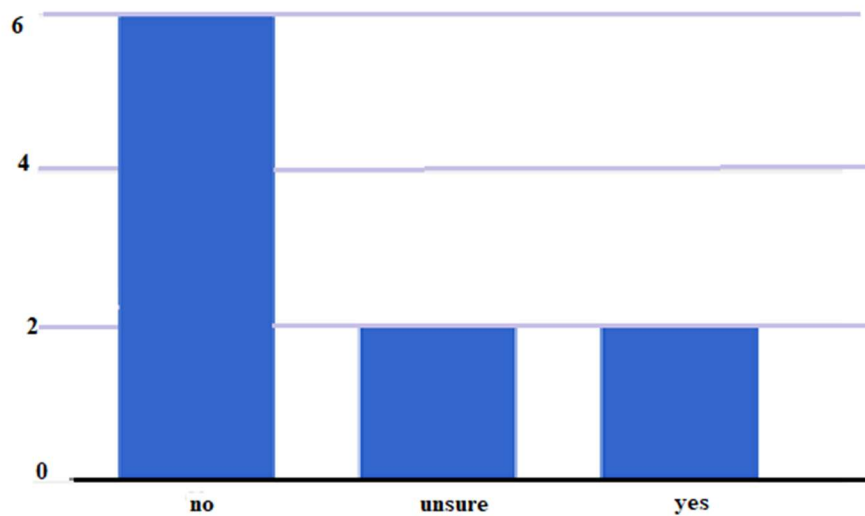


Figure 3. Male students aware of stereotype.

Do you agree with the statement: "I can't be true to myself in the math classroom"?

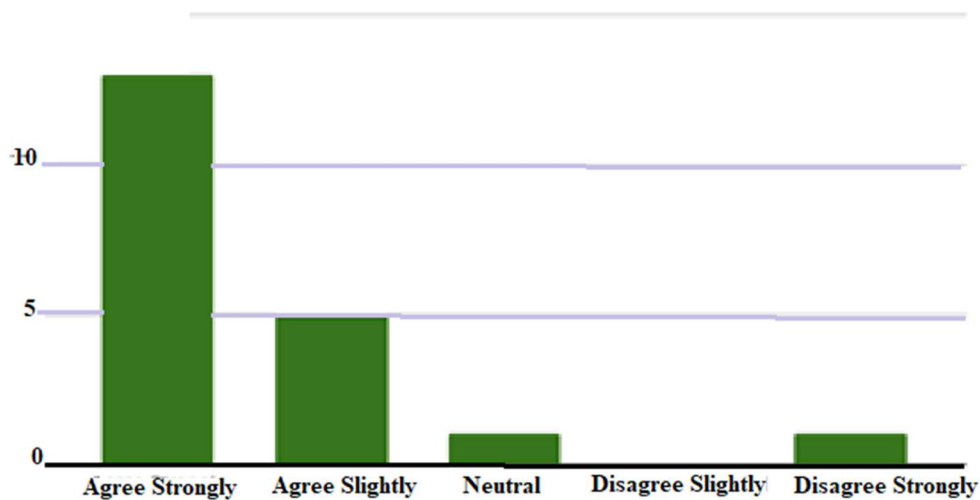


Figure 4. "I can be true to myself in the math classroom."

On the teacher survey, the teacher answered “unsure” to the question, “Have you ever heard of the phrase ‘Stereotype threat?’”. When discussing with the researcher, the teacher said that while he had heard the phrase before, he answered unsure because he was not clear on what it meant in the context of education, nor did he have faith in the vague definition he knew. However, even though stereotype threat was not at the forefront of this teacher's mind, he was using some of the strategies to lessen the effects of stereotype threat. For instance, when asked if he agreed with the statements, “I feel like my students can be true to themselves in my math classroom,” and “I believe in my students regardless of factors of gender, race, religion, or sexual orientation.” The teacher answered “Agree Strongly.” The teacher also answered “Agree slightly” when asked about the statement, “My students know I believe in them.” Conversely, when the students were asked about being true to themselves in the classroom, the students almost all answered that they “Agree Strongly” (Figure 4). This data shows that the teacher has worked to create an identity-safe classroom for his students, one of the three ways of mitigating stereotype threat effects.

The results showed that the majority of students did not know about stereotype threat. The question on the survey that measured this simply asked the students, “Have you ever heard the phrase, ‘Stereotype Threat?’” to which 12 students answered “No,” six students answered “Unsure,” and only two students answered “Yes.” This indicates that most students have not been presented this concept, in a classroom setting or elsewhere.

Lastly, after the discussion with the students, they were asked whether or not they felt like their teacher was effective in combating stereotype threat. The majority of students, 13, answered, “Yes,” four students answered, “Unsure,” and three students answered, “No.”

DISCUSSION

The results of this study did not support one of the hypotheses, strongly supported another hypothesis, and left the other two still with more research needed. For the first hypothesis, that students are aware of the stereotype but are not necessarily aware of stereotype threat was shown to be only partially true: yes, students do not have an awareness of stereotype threat as a phenomenon, but the stereotype about the perceived relationship between gender and mathematics was also missing: many students even wrote on their follow-up survey statements including “I don't believe that stereotype is true, I've never come [sic] across this stereotype. You control your own grades no one else,” and “No, I believe this stereotype is lessening in the modern world and I do not believe in this stereotype.” These students (both male and female) were firmly set in their beliefs that this stereotype was false, and did not have any understanding of how anyone could perceive this stereotype as true. One student even wrote about how he felt that “in fact girls are sometimes better at math than guys.”

The second hypothesis, that female students are more likely to be aware of the negative stereotype was found to be false: when compared by gender, male and female students had the exact same percentage who had been previously aware of that stereotype. This shows that even though the stereotype is about female students, it is not more likely, at least in this group of students for female students to be aware of this stereotype about them.

The third hypothesis, that teachers are aware of stereotype threat was not supported by the results of this survey. The teacher studied was unsure of the meaning of stereotype threat, and as mentioned answered “unsure” when asked if he had knowledge of stereotype threat. Since the teacher did not have enough previous knowledge of stereotype threat, he would have no ability to actively try to prevent the effects of stereotype threat from coming into play in his classroom. However, with only researching one teacher it is still nearly impossible to make a conclusion about a hypothesis based on one subject.

The last hypothesis was shown to be true: even if a teacher is not actively trying to prevent stereotype threat in the classroom, there will still be some of the preventative measures in place that mitigate the effects of stereotype threat because they are simultaneously practices that make the classroom a better environment. This study showed that despite the teacher’s lack of knowledge, the teacher did work on creating an identity safe classroom. The majority of his students did feel like they could be true to themselves in his classroom, and the teacher also reported that he worked hard to make sure all his students felt included and safe in his classroom, regardless of factors including gender, sexual orientation, race, and religion. These actions would combat stereotype threat if students were feeling it regardless of whether or not it was the teacher’s motivation when creating that environment.

The results of this study indicate that not only is stereotype threat less of an issue in this school environment than was initially believed, and that the best practices of teachers can combat stereotype threat without intention. A teacher who is acting in the best interests of his/her students will be effective in combating stereotype threat even without that being his/her original intent.

LIMITATIONS

This study was limited to a single classroom, and this classroom is in a moderately affluent community. The majority of the students were white, and middle to upper-middle class, and may not give an accurate picture of the attitudes and beliefs of diverse learners across the country. These students’ privileges have a direct correlation with the beliefs they have grown up hearing. This study included only 20 students, which resulted in each data point having a strong impact on overall trends.

FUTURE RESEARCH

Future research would go back and look at different classrooms to see if what was seen in this classroom is common for awareness of the stereotype about female students and mathematics, if it is truly becoming less of a prevalence in our school systems, or if this classroom was an anomaly. Extending the study across social class lines, and to more classrooms for a diverse picture of attitudes and thoughts by students on this stereotype, would strengthen the results.

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Appendix A: Survey on Student Opinions: Math, Gender and Stereotype Threat.

Note: This survey is *completely anonymous*. The outcomes of this survey will not affect any grades or classwork for any of the participants. ***Please Answer Honestly.***

1. What gender are you?

- (a) Female
- (b) Male
- (c) Non-binary/Other

2. What gender is your math teacher?

- (a) Female
- (b) Male
- (c) Non-binary/Other
- (d) I don't know

3. Have you ever heard someone say something similar to "boys are better at math than girls?"

- (a) yes
- (b) no
- (c) unsure

4. Do you believe that boys are better at math than girls?

- (a) Definitely yes
- (b) Maybe yes
- (c) maybe no
- (d) Definitely no
- (e) Unsure

For the questions 5-15, please rate how much you agree or disagree with the statement given.

5. "In my math class, boys answer more questions than girls."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral

- (d) Disagree Slightly
- (e) Disagree Strongly

6. "In my math class, my teacher is more likely to call on male students than female students."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

7. "My gender affects how well I do in math class."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

8. "I put more pressure on myself in math class because of expectations about my gender"

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

9. "My peers expect me to do worse in math class because of my gender"

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

10. "My teacher expects me to do worse in math class because of my gender"

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

11. “My family expects me to do worse in math class because of my gender”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

12. “I feel like I can be true to myself in my math classroom.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

13. “My teacher believes in me.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

14. “I feel confident in my math abilities.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

15. Have you ever heard of the phrase *stereotype threat*?

- (a) yes
- (b) no
- (c) unsure

16. If you have heard of stereotype threat, please write anything you know about it (If you have not heard of stereotype threat, just write “Not Applicable”):

17. If you have heard of stereotype threat, where have you heard it? (Choose all that apply)

- (a) Teachers
- (b) Parents
- (c) Friends/Peers
- (d) Online
- (e) Book/Printed Publication
- (f) Other (please say where): _____
- (g) I have not heard of stereotype threat

Thank you very much for completing this survey!

Appendix B: Survey on Teacher Opinions: Math, Gender and Stereotype Threat.

Note: This survey is *completely anonymous*. The outcomes of this survey will not be given to any students, parents, or administrators. ***Please Answer Honestly.***

1. What gender are you?

- (a) Female
- (b) Male
- (c) Non-binary/Other

3. Have you ever heard someone say something similar to “boys are better at math than girls?”

- (a) yes
- (b) no
- (c) unsure

4. Do you believe that boys are better at math than girls?

- (a) Definitely yes
- (b) Maybe yes
- (c) maybe no
- (d) Definitely no
- (e) Unsure

For the questions 5-15, please rate how much you agree or disagree with the statement given.

5. “In my math classes, boys answer more questions than girls.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

6. “In my math class, I am more likely to call on male students than female students.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly

(e) Disagree Strongly

7. “My students’ genders affect how well they perform in math class.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

8. “In the past (when I was a student), my gender has affected my experience in a math classroom.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

9. “I work hard to make sure that my students’ identities are accepted in my classroom.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

10. “I have higher expectations of my male students than my female students.”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

11. “My family expects me to do worse in math class because of my gender”

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

12. "I feel like my students can be true to themselves in my math classroom."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

13. "I believe in my students, regardless of factors of gender, race, or sexual orientation."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

14. "My students know I believe in them."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

15. "I would talk to my students about stereotype threat."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

16. "I work hard to make sure my students are not affected by stereotype threat."

- (a) Agree Strongly
- (b) Agree Slightly
- (c) Neutral
- (d) Disagree Slightly
- (e) Disagree Strongly

17. Have you ever heard of the phrase *stereotype threat*?

- (a) yes
- (b) no
- (c) unsure

18. If you have heard of stereotype threat, please write anything you know about it (If you have not heard of stereotype threat, just write “Not Applicable”):

19. If you have heard of stereotype threat, where have you heard it? (Choose all that apply)

- (a) Other teachers
- (b) Parents
- (c) Administrators
- (d) College Education Classes
- (e) Professional Development
- (f) Friends/Social Settings
- (g) Online
- (h) Book/Printed Publication
- (i) Other (please say where): _____
- (j) I have not heard of stereotype threat

Thank you very much for completing this survey!

Appendix C: Follow-Up Student Survey

What gender do you identify as?

- (d) Female
- (e) Male
- (f) Non-binary/Other

Do you feel that your teacher is effective in lessening the effects of stereotype threat?

- (a) Yes
- (b) No
- (c) Unsure

Now knowing what stereotype threat is, how have your feelings about the stereotype female students performance in math changed?

The Relationship Between Assessment Practices and Hispanic and White Eighth Grade Students' Mathematics Achievement: An Analysis of 2013 NAEP Data

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***Abstract:** This study examined data from the 2013 NAEP eighth grade mathematics assessment. This correlational analysis related to classroom assessment practices, from the teacher survey, with students' mathematics achievement. Multiple regression analyses were also conducted to examine the relationship between the frequency of use various assessment strategies and student mathematics achievement. The results showed that Hispanic students' mathematics performance was at a lower level than non-Hispanic (White) students. Items related to formative assessment strategies were correlated with achievement. There was a negative relationship found when discussing current performance level of students. Both groups of students had lower mean composite scores as the reported frequency of use increased. In addition, a negative relationship was found when teachers reported assessing students by adjusting teaching strategies to meet the needs of students and achievement. The findings suggest that formative assessment strategies have a negative relationship with the Nation's eighth grade mathematics students.*

Keywords: NAEP, mathematics, eighth grade, student achievement

There are many views that suggest that the use of assessment strategies impact student achievement. The National Council of Supervisors of Mathematics (2014) and the National Council of Teachers of Mathematics (2014) have issued position papers affirming the use of assessment including formative assessment. Yet, there have been few studies that examine the impact of assessment strategies on middle school students' mathematics achievement. Erasmus (2014) developed an overall assessment system for second language learners, which involved cognitive facets, affective facets and screening tests, but no examination of a particular strategy on mathematics achievement. William, Lee, Harrison, & Black (2004) studied the impact of teachers developing assessment strategies on student achievement on accountability tests.

The purpose of this study was to examine the relationship between various assessment strategies and Hispanic and White eighth grade mathematics achievement on the 2013 National Assessment of Education Progress (NAEP) test. The research questions were: What is the difference between Hispanic and White students' achievement on the eighth grade NAEP mathematics exam? What is the relationship between assessment practices and performance of Hispanic and White students on the eighth grade NAEP mathematics exam? What is the relationship between formative assessment strategies and performance of Hispanic students and White students on the eighth grade NAEP mathematics exam?

REVIEW OF RELATED LITERATURE

Hispanic Education

The educational attainment of United States Hispanics has been changing over the last several years (Krogstad, 2016). This is reflected in a growing number of Hispanics' students in the nations' K-12 Schools. In 2014, it was projected that the public schools in the United States would be majority-minority, with a large percentage being Hispanic (Krogstad & Fry, 2014). Since 1997, the number of Hispanic students has almost doubled to 12.9 million in 2014 According to Krogstad & Fry, most of the growth is due to U.S. born Hispanics.

As noted, the portion of the U.S. Hispanic population is increasing over time. A substantial proportion of this growing Hispanic student population in grades 4 and 8 are English language learners with 37 percent and 21 percent respectively (Hemphill & Vanneman, 2011). Both the growing population of Hispanic students and the larger portion that are English language learners contribute to the achievement gap between Hispanic and White fourth and eighth graders (Hemphill & Vanneman, 2011). The National Center for Education Statistics (NCES) [2015] defines an achievement gap as "when one group of students such as, students grouped by race/ethnicity, or gender outperforms another group, and the difference in average scores for the two groups is statistically significant." Closing an achievement gap can be a challenge especially the one between Hispanic and White students, even though Hispanic students' average scores have

increased across the assessment years, White students had higher scores across all assessments (Hemphill & Vanneman, 2011).

The National Assessment of Educational Progress (NAEP) mathematics exam was first administered to both Hispanic and White public school students in 1990. Hemphill and Fry's (2011) report indicated that on the 2009 NAEP mathematics exam, the scores for both Hispanic and White students in grades 4 and 8 were higher than in 1990. However, from 1990 to 2009, the achievement gap between Hispanic and White students did not change significantly at either grade four or eight. Scores for Hispanic and White fourth-graders remained unchanged from 2007 to 2009, and the gap persisted at 21 points. For eighth-graders, scores increased for both Hispanic and White students from 2007 to 2009, but the gap remained at 26 points, and it was not significantly different from the gap in 1990 or 2007 (Hemphill & Vanneman).

The achievement gap between Hispanic and White students seems to be persistent with little change. Moreover, it is essential to be concerned with Hispanic student achievement in relation to future high school mathematics course taking and in science, technology, engineering, and mathematics (STEM). Hispanic students are underrepresented among students who complete a four-year degree in science, technology, engineering and mathematics (Borman, et al., 2017; National Center for Education Statistics, 2016). The more advanced high school courses that are taken the greater the likelihood that students will enroll in college and complete a degree (Hinojosa, Rapaport, Jaciw, LiCalsi, & Zacamy, 2016).

Without an adequate foundation in mathematics and by not having access to advanced courses, Hispanic students may be at a disadvantage when seeking STEM related career opportunities (Garland & Rapoport, 2018). In 2009 Hispanic employees accounted for 14 percent of the U.S. workforce but held only 6 percent of STEM jobs (Beede et al., 2011). Garland & Rapoport (2018) conducted a study in Texas, a state where 51 percent of its students are Hispanic, found that White students completed a slightly greater number of advanced STEM courses. In addition, a greater difference by race/ethnicity was found for the percentage of students who completed three or more advanced STEM courses. They found that among high ability grade 8 students, approximately 52 percent of White students completed three or more advanced mathematics courses during high school compared with 41 percent of Hispanic students. This observation suggests that there is a need to examine mathematical instructional practices that offer the best chance for promoting student achievement and thus advanced course taking in STEM fields (Garland & Rapoport).

Feedback as Formative Assessment

It is widely believed that formative assessment enlightens students on their strengths and weaknesses (Phelan, Choi, Vendlinski, Baker, & Herman, 2011). Also, it is suggested that

formative assessment fosters large learning gains, especially for low-achieving students (William, Lee, Harrison, & Black, 2004). Controversy exists regarding this issue. In recent meta-analyses that analyzed the impact of formative assessment on student achievement Kingston & Nash (2011) concluded that the use of formative assessment produces a 0.2 median effect size. In response, Briggs, Ruiz-Primo, Furtak, Shepard and Yin (2012) questioned the methodology of the Kingston and Nash study in four areas: (a) its approach, (b) inclusion criteria, (c) biased effect sizes, and (d) the relationship between effect sizes and the magnitude of the outcomes. They concluded that the effect size reported by Kingston and Nash is not accurate. Kingston and Nash's finding suggested that the use of formative assessment strategies may not have as great an impact as indicated by others reporting an effect size ranging from 0.4 to 0.7 (McMillan, Venable & Varier, 2013). Apparently, the promise of formative assessment indicated by some studies may be difficult to fulfill (Phelan et al., 2013).

Formative assessment researchers have widened their scope by examining teacher professional development (Wylie & Lyon, 2015) and special populations. For example, a study conducted by Shayyan, Thurlow, and Liu (2008) on English Language Learners with disabilities attempted to determine effective instructional strategies. They identified 10 strategies upon examination of the literature. Two strategies in particular relate to formative assessment of students: (1) provide feedback that is adapted to the learner's level of language proficiency, and (2) conduct on-going assessment of the effectiveness of instruction. Similarly, students in their study weighted as a highly important instructional strategy the use of random, recurrent assessment. In contrast, educators in the same survey rated highly important the assessment strategy of having students think aloud. These strategies are appropriate for all students. Hudson (2015) suggested that assessment should be on going, dynamic and provide feedback to students.

Furthermore, feedback has also become an area for formative assessment research, which is regarded as an essential component of formative assessment (Hattie & Timperley, 2007; Hattie, 2009). Havnes, Smith, Dysthe, and Ludvigsen (2012) noted that positive effects from the use of feedback do not always occur. They cited a 1996 study by Kluger and DeNisi who found that more than one third of the effects indicated negative impact of feedback on learning. However, Havnes et al contended that in order for feedback to be formative, there is an assumption that the feedback should be provided in a manner that actively engages the learner with the feedback. This suggests that the learner plays a role in how feedback is used and interpreted (Sadler, 2010). Havnes et al examined perceptions of feedback practices of teachers, and how the feedback is used by teachers and students using surveys and focus groups. Their findings suggested that feedback practice is subject related, different content areas have different methods and purposes for feedback, and that weak students are not able to use feedback provided by the teachers. Their other findings suggested that practices related to assessment were found to focus on corrections and grading and that communication about learning processes between the teachers and the students

was viewed as formative assessment. They identified four classroom situations that have potential to be rich in feedback opportunities: working through a test or assignment when corrected and returned to students, student presentations of group projects, group-work, and discussions between the teacher and the student. Feedback is an integral aspect of the classroom, but the era of accountability has affected assessment practices.

Toward Formative Assessment

Accountability has emphasized the use of standardized tests often in the form of multiple-choice items for use in high-stakes testing (Kantrov, 2000). Teachers use multiple-choice and similar tests in the classroom (Kantrov, 2000). Assessment is considered any systematic procedure for collecting information that can be used to make inferences about students (American Education Research Association, et al, 1999). High-stakes test results are often used to make decisions such as whether or not a student graduates. Important decisions should not be based on a single test or other assessment procedures (Reynolds, Livingston, & Willson, 2009). Assessment is a tool that provides evidence and feedback concerning what students know, a way to communicate the value of knowing important concepts, and determining program effectiveness. Problems persist with the current accountability system (Koretz, 2008). Recognizing these limitations and current assumptions about learning and knowing has led to tensions with newer learning and assessment paradigms (e.g., Hickey & Anderson, 2007; Shepard, 2008; Stiggins, 2002) which have motivated educational researchers to rethink the role of assessment to one where it supports and documents classroom learning.

Assessment of students' capabilities in mathematics begins in the classroom with the teacher. Moreover, assessment as a broad, general term evolves into formative assessment when teachers and students conduct activities that provide information to be used as feedback to modify teaching and learning activities in order to best meet their needs (Black & William, 1998; Havnes, Smith, Dysthe, & Ludvigsen, 2012). The importance of assessment within the classroom is being recognized, and there is a shift from the 'testing culture' to an 'assessment culture' (Filsecker & Kerres, 2012). Shepard (2000) saw the shift emerging as part of the learning process rather than external tests administered at the end of curricular units. Consequently, the assessment paradigm has moved toward classroom assessment, which is characterized as constructivist and learner centered (Filsecker & Kerres, 2012).

A working group called Demos (2004) examined the issue of learning. The group contended that those teachers who constantly monitor their students, as they set about learning and reflect on actions that do not go as expected, were the better teachers. This is otherwise known as assessment for learning that results in an assessment-centered design for a learning environment (Demos,

2004). This points to the notion that formative assessment is a process that occurs in the moment-to-moment interactions between the teacher and students (Filsecker & Kerres, 2012).

Assessment in the Mathematics Classroom

The National Council of Teachers of Mathematics [NCTM] (2014) listed assessment as one of six principles to ensure success for all students, and it was suggested that assessment should support the learning of important mathematics and furnish useful information to both teachers and students. Assessment within an excellent mathematics program ensures that assessment is an integral aspect of instruction providing evidence of what students know about important mathematics content, and includes a variety of data sources from which important decisions can be made concerning students, instruction, and the program (NCTM, 2014). Likewise, Hudson (2015) and Fennel, Swartz, McCord, Kobett, and Wray (2015) contended that formative assessment should be on going, dynamic, and provide detailed and useful feedback. Formative assessment has taken on a more important role in providing this information, and it is viewed as a way to bring about changes in the classroom (Black & William, 2009). It is defined as the extent that actions are taken in the classroom to elicit evidence of student achievement, interpretation of the evidence used by teachers, learners, or their peers to make decisions about the next steps in instruction that would be better founded if the evidence had not been used to make such decisions (Black & William). More succinctly, formative assessment is to inform instruction and provide feedback to students on their learning (Filsecker & Kerres, 2012; & Keeley & Tobey, 2011).

Wylie & Lyon (2015) disaggregated Leahy, Lyon, Thompson, and William's (2005) definition of formative assessment and identified strategies that support the use of assessment by teachers that include clarifying and sharing learning intentions and criteria for success, orchestrating effective discussions, questions, and learning tasks, and providing feedback. Wylie and Lyon (2015) conducted a professional development program, for 200 mathematics and science teachers, in an attempt to evaluate how they implemented the strategies in their classrooms. The program had an introductory two-day workshop for teachers, a follow-up two-day workshop for teacher leaders, and monthly learning community meetings for two years. Participants were asked to complete on-line surveys, supply a daily log indicating which of the 74 assessment strategies were used, and a reflection of implementing one technique with a detailed description of its implementation. Wylie and Lyon (2015) found that the teachers reported a similar frequency of communicating expectations, the use of classroom questions, and tasks prior to the training and two years after the training occurred. The study revealed a change in their teachers' questioning strategies from calling on students with hands raised to a more random approach. There were positive changes in how teachers issued feedback, from commenting only without a grade to mastery grading, the expectation that work will be revised based upon feedback until it reaches an acceptable standard. However, on the reflection piece, they noted that the teachers reported communicating learning

expectations more often than criteria for success and an increased use of collecting student evidence of learning. This study examined the frequency of use of formative assessment strategies following a professional development program. A weakness in the study is that student achievement was not examined relative to the frequency of use of the five strategies. Mathematics teachers often use performance-based, embedded assessments such as problem sets, writing in journals, providing immediate or delayed feedback from the use of summative tests, and questioning (Keely & Tobey, 2011). Consequently, the teacher in an assessment-centered classroom must continuously note how to meet the learning needs of students and build a bridge between their initial ideas and mathematics instructional goals (Keely & Tobey; William, 2011).

The above discussion centers on describing assessment and formative assessment. Good (2011) contended that formative assessment has long been described as a type of assessment, and believes that it is a process; at issue is the timing regardless of the quality of item or its connection to instruction. An example was provided to assess student understanding of the order of operations: $3^2 + 2 \times 4$ which can be used as either a summative, if administered at the end of a unit or formative item if used to identify misconceptions during instruction (Good, 2011). So, assessment items, tasks, or activities like mathematics exercises may be considered formative or summative depending on how they are used.

In the current study, the term assessment is being used to encompass formative assessment strategies. In summary, Dunn & Mulvenon (2009) concluded that there have been few studies that have examined the impact of assessment strategies on student achievement. There have been some studies such as Black and William's (1998) study concluding that formative assessment does improve learning. Others such as Bennett (2011), Filsecker & Kerres, (2012), and Kingston and Nash (2011) have addressed generally, the degree to which formative assessment affects achievement (McMillan, Venable & Varier, 2013). The meta-analysis conducted by Kingston and Nash investigated the relationship and found a median effect size of 0.20, which is lower than the range cited often of 0.4 to 0.7 (McMillan et al., 2013). McMillan et al critiqued Kingston and Nash's study on three grounds: (1) the quality of the studies used, (2) selection criteria for the studies used in the meta-analysis, and (3) and the nature of the formative assessment strategies used. Others have examined the impact of professional development such as, Wylie & Lyon (2015) who examined the fidelity of the implementation of a professional development program for mathematics and science teachers in formative assessment and found that the use of feedback, and its quality improved as a result training in formative assessment strategies. Phelan et al. (2011) conducted a randomized study that examined the implementation of sixth grade formative assessment tasks in various mathematics domains. They found that, overall, the treatment students did not outperform control students, and the students who scored higher on the pretest benefited more from the intervention compared to students who scored lower on the pretest. This result means that higher performing students benefited the most from implementing formative

assessments. The intervention did not help lower performing students develop greater understanding of the mathematics concepts. Given that the Phelan et al. study is an example of determining the impact of formative assessment on student mathematics understanding; there are relatively few studies that have examined the relationship between formative assessment strategies and middle school mathematics students' achievement. The current study aimed to determine the relationship between formative assessment strategies and student achievement.

METHODS AND PROCEDURES

Instrument

The 2013 NAEP National Public School database was the data source for the analysis. The sample consisted of eighth grade students. Teachers of students who were administered the assessment were asked to complete a questionnaire. The survey contains items related to classroom instruction and practices. The independent variables were selected from the teacher reported data regarding the modes of instruction/classroom activities, in particular those that were considered assessment strategies and/or formative assessment techniques. These included: Approximately how much mathematics homework do you assign to students in your mathematics class each day? The responses for this item were None, Less Than an Hour, About 1 hour, About 2 – 3 hours, and More Than 3 hours. Teachers were to respond to items by describing the frequency of use for particular strategies, such as:

- Assess math students by discussing current performance level,
- Assess math students by adjusting teaching strategies to meet needs,
- Assess math students by discussing progress toward goals,
- Assess math students by setting goals for specific progress,
- Assess math with individual or group projects,
- Assess math with multiple-choice tests,
- Assess math with problem sets,
- Assess math with short or long written responses.

For these items the response choices are (1) Never or Hardly Ever, (2) A Few Times a Year, (3) Once or Twice a Month, (4) Once or Twice a Week, (5) Every Day or Almost Every Day. The response options were different for the item, "Amount of math homework assigned per day." They were (1) None, (2) Less than One Hour, (3) About One Hour, (4) About two to three Hours, (4) More than Three Hours. Significance tests and Multiple regression analyses were conducted using

the questionnaire items as independent variables and the Composite Mathematics Plausible Value Score as the dependent variable. The analysis focused on Hispanic and White student ethnic groups.

NAEP Sampling Procedures

NAEP (2011) uses complex sampling procedures to limit the error and bias in sampling. Students were randomly selected from schools. Sampling strata for schools are developed from groups like school, Region, Urbanicity, Minority composition and Enrollment. The schools are sampled with probability proportional to size of enrollment. It is noted that each stratum can have a different sampling rate. Sampling weights are then computed to counter-act the unequal probabilities of selection and ensure unbiased estimates for the Nation. In order to account for unequal probabilities of selection, sampling weights were used in the analysis. Variance estimates related to the Clusters are combined to account for cluster dependencies from separate estimates from within clusters. Jackknife procedures are used to handle clustering to create replicate weights. Taylor series is used to obtain an approximation to some nonlinear estimating function that is applied to the Primary Sampling Unit with the stratum; thus creating a final weight, Strata, and cluster identifiers to combine estimates of means and variances within each cluster. Plausible values are created and used in the analysis of scores.

Results

The overall performance of the nation's middle school Hispanic students was lower than White students and statistically significant by 23.5 points. Table 1 below presents the mean Composite Scores for items identified as formative feedback techniques. Hispanic students scored lower than White students in each category. It appears that for Hispanic students, when discussing progress toward goals every day or almost every day, the scores were on average 34.6 points lower than not at all in comparison to White students. White students had nearly 9 points higher when their progress was discussed nearly each day compared to not at all. These were statistically significant results.

When setting goals, those teachers who reported Never or Hardly Ever, Hispanic students scored statistically significantly lower than White students 275 and 298 respectively. There were decreases in the means for each category and for each ethnic group. For Hispanic students, their mean was 263 when teachers reported discussing progress nearly each day, a 12-point difference from the category Never to the category Hardly Ever. For White students, the result is similar but with a drop of 8 points.

The pattern continues for assessing math students by discussing their current performance level. Both groups had higher means for the Never or Hardly Ever category and the mean performance tended to decrease within each of the subsequent categories. For Hispanic students

the means fell from 274 in Never to Hardly Ever to 269 in Everyday or Almost Everyday, and for White students the means ranged from 301 to 290 in the same category. The differences in performance when teachers reported assessing math students by adjusting teaching strategies to meet needs were less pronounced. In other words, the drop in scores from Never or Hardly Ever to Everyday or Almost Everyday was smaller. However, Hispanic students still performed at a lower level than White Students. The difference was 6 points for Hispanic students and 5 points for White students.

Table 1

Mean Mathematics Composite Scores and Standard Errors for Items Related to Feedback

Item	Never or Hardly Ever	Few Times a Year	Once or Twice a month	Once or Twice a Week	Everyday or almost Everyday
Assess math students by discussing progress toward goals.	Hispanic 274 (1.6) White 299 (0.6)	Hispanic 273 (1.6) White 296 (0.6)	Hispanic 274 (0.9) White 294 (0.4)	Hispanic 271 (0.8) White 290 (0.5)	Hispanic 264 (3.1) White 290 (1.7)
Assess math students by setting goals for specific progress.	Hispanic 275 (1.9) White 298 (0.6)	Hispanic 273 (0.7) White 296 (0.64)	Hispanic 274 (0.7) White 294 (0.5)	Hispanic 270 (1.3) White 291 (0.8)	Hispanic 263 (3.1) White 290 (1.4)
Assess math students by discussing current performance level.	Hispanic 274 (4.6) White 301 (1.8)	Hispanic 273 (1.0) White 297 (0.4)	Hispanic 272 (0.7) White 295 (0.4)	Hispanic 270 (0.9) White 293 (0.5)	Hispanic 269 (1.8) White 290 (1.0)
Assess math students by adjusting teaching strategies to meet needs.	Hispanic 276 (2.9) White 299 (1.1)	Hispanic 273 (1.2) White 296 (0.7)	Hispanic 272 (0.8) White 296 (0.6)	Hispanic 272 (0.7) White 292 (0.5)	Hispanic 270 (1.0) White 294 (0.5)

Table 2 presents Mean Composite Scores for items that may or may not be formative assessment depending upon the timing. However, these are considered by the researcher to be assessment strategies that include performance and objective tasks. The achievement gap persists for these items. For Hispanic students, the gap between when teachers reported assessing math with individual or group projects was smaller than for White students, with 4 points and 9 points respectively. Hispanic students had a higher mean of 274 than any other category when teachers reported doing this One to Two times per year. The result was similar for White students. Students

whose teachers reported rarely using multiple-choice tests one to two times per year to assess them had higher achievement, 299 for White students and 276 for Hispanic students. Teachers who reported using multiple choice tests one to 2 times per week had students with lower scores compared to Never or Hardly Ever using multiple-choice tests. The use of problem sets was found not to show significant differences between the frequencies of use.

Hispanic students whose teachers who reported using short or long written responses for assessing math had similar scores in each of the frequency categories ranging from 270

for Never or Hardly Ever to 272 for 1 to 2 times a Month and 1 to 2 times a week. White students had a similar pattern going from 292 to 295 at 1 to 2 times a year.

Table 2

Mean Mathematics Composite Scores and Standard Errors for Items Related to Assessment Activities

Item	Never or hardly ever	1 to 2 times a Year	1 to 2 times a Month	1 to 2 times a Week
Assess math with individual or group projects.	Hispanic 270 (1.0)	Hispanic 274 (0.7)	Hispanic 270 (1.0)	Hispanic 266 (2.6)
	White 295 (0.6)	White 296 (0.4)	White 294 (0.6)	White 286 (1.8)
Assess math with multiple-choice tests.	Hispanic 272 (1.4)	Hispanic 276 (1.4)	Hispanic 271 (0.6)	Hispanic 269 (1.3)
	White 298 (0.6)	White 299 (0.5)	White 293 (0.4)	White 289(1.0)
Assess math with problem sets.	Hispanic 272 (2.3)	Hispanic 270 (2.5)	Hispanic 270 (0.8)	Hispanic 273 (0.6)
	White 295 (1.4)	White 295 (1.5)	White 295 (0.5)	White 295 (0.3)
Assess math with short or long written responses.	Hispanic 270 (1.9)	Hispanic 271 (1.1)	Hispanic 272 (0.7)	Hispanic 272 (0.7)
	White 292 (1.1)	White 295 (0.8)	White 296 (0.4)	White 295 (0.5)

Table 3 presents the results for the use of homework. This was selected because traditionally homework can be used as a form of assessment, whether summative or formative. The results are similar in relation to the achievement gap. However, in the category About One Hour of Homework, the mean scores were greater than the other categories regardless of ethnicity.

For Hispanic students the mean was 275 and for White students the mean was 301. Compare these scores to the scores whose teachers reported ‘None,’ 260 and 273 for Hispanic and White students respectively.

Table 3

Mean Mathematics Composite Scores and Standard Errors for Frequency of Homework

Item	None	Less than One Hour	About One Hour	About 2 to 3 Hours	More than 3 Hours
Amount of math homework assigned per day.	Hispanic 260 (3.1)	Hispanic 271 (0.4)	Hispanic 275 (1.2)	Hispanic 271 (6.7)	Hispanic 270 (9.2)
	White 273 (1.6)	White 295 (0.3)	White 301 (0.7)	White 292 (2.8)	White missing

Table 4 presents the multiple regression results for each of the items from the teacher survey related to assessment as selected by the researcher. There was a negative association between adjusting instruction to meet the needs of students and student achievement; the greater the reported frequency, the lower the achievement of students whose teachers were administered the survey. A negative relationship was found for assessing math students by setting goals, discussing current performance level, and discussing progress toward learning goals with student achievement. It appears, taken as a whole, the strategies that may be considered formative assessment strategies such as those that provide feedback to students have a negative relationship with achievement in mathematics.

Assessing students with individual or group projects was found to have a positive relationship with achievement when the use is 1 to 2 times a year. There is a negative relationship for the use of projects beginning at one to two times a month with a regression coefficient of -1.01 and -7.10 for 1 to two times a week. A similar result occurred for the use of multiple-choice tests. When teachers reported using them once or twice a year there was a positive relationship with achievement, but negatively associated with achievement at the frequency of one to two times a month and one to two times a week. Assessing math with short or long written responses at least one or two times a month was positively related to achievement, where there was a regression coefficient of 2.76, and suggested that students whose teachers reported providing this opportunity scored nearly three points higher when compared to students whose teachers reported Never or Hardly Ever requiring long or short written responses.

Table 4

Multiple Regression Analyses for Teacher Survey Formative Assessment Items Related to Student Achievement

Comparison code: Never or Hardly Ever	Intercept	Regression Coefficients	S. E. of Regression Coefficients	P-Value	R-Squared
Assess math students by adjusting teaching strategies to meet needs.	299.84				0.141
A few times a year		-3.15	1.35	0.023	
Once or twice a month		-4.32	1.29	0.001	
Once or twice a week		-6.90	1.28	< 0.001	
Every day or almost every day		-6.62	1.36	< 0.001	
Assess math students by setting goals for specific progress.	298.33				0.412
A few times a year		-2.25	0.83	0.008	
Once or twice a month		-4.93	0.97	< 0.001	
Once or twice a week		-6.61	1.14	< 0.001	
Every day or almost every day		-9.89	1.82	< 0.001	
Assess math students by discussing current performance level.	299.85				0.140
A few times a year		-3.15	1.97	0.11	
Once or twice a month		-4.88	1.97	0.02	
Once or twice a week		-7.17	2.06	0.001	
Every day or almost every day		-9.12	2.07	<0.001	
Assess math students by discussing progress toward goals.	298.07				0.412
A few times a year		-1.96	0.83	0.021	
Once or twice a month		-4.57	0.88	<0.001	
Once or twice a week		-7.03	1.05	<0.001	
Every day or almost every day		-9.74	1.78	<0.001	

Assess math with individual or group projects.	294.41				0.139
1-2 times a year		1.79	0.63	0.006	
1-2 times a month		-1.01	0.76	0.192	
1-2 times a week		-7.10	1.51	<0.001	
Assess math with multiple-choice tests.	296.38				0.143
1-2 times a year		2.21	0.80	0.007	
1-2 times a month		-3.00	0.72	<0.001	
1-2 times a week		-6.51	0.95	<0.001	
Assess math with problem sets.	294.55				0.138
1-2 times a year		1.11	2.15	0.52	
1-2 times a month		-0.30	1.39	-0.21	
1-2 times a week		0.62	1.27	0.49	
Assess math with short or long written responses.	292.82				0.138
1-2 times a year		1.40	1.32	0.297	
1-2 times a month		2.76	1.10	0.014	
1-2 times a week		1.93	1.20	0.113	
Amount of math homework assigned per day. (contrast: None)	276.95				0.416
Less than 1 hour		18.03	1.62	<0.001	
About an hour		21.70	1.65	<0.001	
About 2 – 3 hours		18.33	4.35	<0.001	
More than 3 hours		16.21	5.53	<0.001	

Summary of Results

The mathematics achievement of Hispanic students was statistically significantly lower than the performance of White students for each of the selected formative assessment items, and in overall performance. Recall that NAEP collects teacher survey data from students who were selected to take the assessment. Multiple regression analyses were conducted, using the frequency, ‘Never or Hardly Ever,’ as a comparison for each of the above items.

It appears that feedback related activities were negatively associated with mathematics achievement. This parallels Phelan et al.'s (2011) study where formative assessments had little impact on low performing students' achievement in mathematics. When teachers reported a greater frequency of adjusting instruction to meet the needs of students, the scores were lower for Hispanic students. When compared to Never or Hardly Ever, adjusting instruction to meet the needs of students was statistically negatively associated with achievement. Similarly, a negative relationship was found for setting goals for specific progress and achievement. The regression analysis indicated that scores were nearly 10 points lower for doing this nearly every day. Also, discussing current student performance level, and discussing progress toward goals were found to be negatively associated with achievement, with a gap of nearly nine points for each activity. Mathematics achievement was positively related for students whose teachers reported using individual or group projects one to two times a year; and negatively related with mathematics achievement when teachers reported using them more often with students. An infrequent use of multiple-choice tests for assessment was positively associated with mathematics achievement; more frequent use of multiple-choice tests for assessment was negatively related to achievement. The use of problem sets is not related to achievement. This seems to contradict Shirvani's (2009) findings, if quizzes are considered problem sets. The use of written responses once or twice a month was positively related to achievement; however, more infrequent use or a much more greater use of written responses for assessment were negatively related to achievement. Finally, the frequency of Homework was positively related to achievement. Students of teachers who reported assigning about one hour of homework scored nearly 21 points higher than those students whose teachers Never or Hardly Ever assigned homework.

Implications

The findings of the current study showed that both Hispanic and White students had similar patterns of achievement in relation to the selected items, although Hispanic students had lower achievement than White students. The nation's Hispanic students scored lower than White students in almost every category. The current study revealed that assessment practices such as discussing with mathematics students their current performance levels, setting learning goals and discussing their progress toward those learning goals are not generally effective for assisting Hispanic students.

These findings, on the surface, appear contrary to current thought about assessment in mathematics, in particular, formative assessment related to feedback. The current study's findings suggest that there is a negative relationship between assessment and mathematics achievement of the nation's eighth graders. Prior studies, including Kingston and Nash's (2011) meta-analysis, although controversial suggested a 0.20 effect size, which indicated higher achievement when formative assessment is used. Ruiz-Primo & Furtak (2007) observed teachers' use of formative

assessment strategies in science and found a 0.92 effect size, which also suggested higher achievement when feedback is used.

The current study's results were determined through the use of multiple regression analysis on the NAEP teacher survey items and their students' scores comparing the frequencies to not doing any of the actions. The findings may be explained by noting that perhaps the teachers who self-reported doing various techniques more often had lower performing students in general. This brings into question what is the quality of the discussions and feedback shared with students in a way that they contributed to what they should do to improve their scores measured by the survey. Hence, it is the quality not the quantity of feedback and discussions that can assist all students to improve their achievement.

Phelan et al. (2011) indicated challenges when trying to fulfill the promise of formative assessment including teachers who often have limited background and capacity to develop or engage in high quality assessment practices. The criteria for formative assessments must be made clear and quality feedback must be provided to students in a timely manner so that they can understand what they need to do to improve at the same time as being engaged in the feedback process.

Other findings suggested that assigning moderate amount homework, about one hour each day, is positively related to achievement. A frequent use, at least once or twice a month, of short or long writing appeared to be positively related to achievement. This demonstrates the efficacy of such a strategy as the best way to provide feedback through moderate amounts of hands-on mathematical tasks of all the listed strategies. It is not known how much effort does the teacher put forth to have students go to the board to provide answers during class and the degree to which students are engaged in rigorous mathematics tasks (NCTM, 2014), which ties into the homework process.

The results related to providing feedback, as noted above was perplexing. A possible explanation may be due to the teachers who reported using formative assessment more often might be teaching lower achieving students. It is contrary to what other studies have found regarding the potential benefit of offering feedback. Perhaps this is due to the way the NAEP items are written. It is unclear whether the teachers conduct those actions with students or other teachers. The students of teachers who reported greater frequency of adjusting instruction to meet student needs had lower achievement. This is a surprising finding. Also, discussing the performance levels and using discussions both were negatively related to achievement, the greater the frequency of occurrence was related to sharply lower achievement scores, although the weakest students can have instruction adjusted and still not be engaged. Teachers, who reported a moderate level of assigning projects to assess mathematics, Once or Twice a Month, had students with higher achievement scores compared to Not Hardly Ever assigning projects. This finding suggests that projects have

the potential to improve student achievement and should be regularly incorporated into instruction. Perhaps there should be greater use of more student-centered assessment strategies.

The current study relied on self-reporting of the frequency of doing particular formative assessment related activities by teachers of students who were selected to take the 2015 NAEP exam. Further probing, similar to the Phelan et al. (2011) study, is necessary to gain insight into the impact of formative assessment on middle school students' mathematics achievement. A finer grained analysis could include the examination of teacher implementing formative assessment techniques, teacher knowledge related to assessment and observations of teachers, and student growth while implanting formative assessments (Phelan et al.). With quality feedback and appropriate adjustments to instruction, student achievement in mathematics can be further enhanced through the use of student-centered, hands-on, rigorous mathematics tasks or projects that have the potential to maximize student engagement. These activities are beneficial for both the general population and the Hispanic student population.

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Book Review for *PRIME OBSESSION* by John Derbyshire

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Title: Prime Obsession

Author: John Derbyshire

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The book's title *PRIME OBSESSION* might mislead the eye of mystery buffs, thinking it is an adventure fiction. Only the mathematically aware would discern that it has something to do with prime numbers, and be worthy of perusal. This is how I acquired this intriguing book, rapidly gleaning that it is indeed about the mysteries of prime numbers and the Riemann Hypothesis, with which I was acquainted. The book engages the interested reader with a penchant for mathematical topics, those such as teachers, students, and anyone trained beyond basic mathematics, who seek a friendly but informative view into number theory and analysis, and presented at a level of the average intelligent reader, by way of biography and the methods attempted to solve the problem.

The book's organization into alternating chapters devoted to the biography of Bernhard Riemann, and the other half to an exposition of his Hypothesis, tends to separate the mathematician Riemann from his work. Reading other available accounts could be enlightening. The author's suggestion for reading all of the biography chapters followed by reading all of the technical chapters is a useful adjunct.

Presentation of the hero of the narrative, the nineteenth century mathematical phenomenon Bernhard Riemann, is interesting in terms of scientific biography. Most of what is known of Riemann's personal life has been garnered from his letters to his family. It is difficult to know how much of his mathematical inspiration was from his own ingenuity or from the influence of his teachers of mathematics. The technical development of Riemann's ideas culminating in the Hypothesis is quite good.

His doctorate from Göttingen, containing the Cauchy-Riemann equations of complex analysis as well as the beginnings of Riemann surfaces demonstrates his emerging mastery of the subject.

Riemann's election as a corresponding member of the Berlin Academy necessitated the presentation of a second research (habilitation) thesis to the faculty, in which paper entitled "On the Number of Prime Numbers Less Than a Given Quantity" is the landmark work that includes the Riemann Hypothesis involving the zeta function. We note critically that Riemann evaded any attempt at solution of the Hypothesis in his paper; he claimed that it was not central to his purpose. This would not be acceptable in the contemporary mathematics journals. He died on July 20, 1866, just short of his fortieth birthday. During the nineteenth century such deaths from tuberculosis were common.

The Riemann Hypothesis (RH), the statement of which is repeated as a *leitmotiv* throughout the book, simply says ***all the non-trivial zeros of the of the zeta function have real part one-half.*** Over a century and a half have elapsed and no one has been able to prove, or disprove, this assertion. All that was accomplished over this time are approximation methods to a solution and features of a solution, but no formula (closed form solution) is offered. For reference the Riemann zeta function $\zeta(s)$ is written

$$\zeta(s) = 1 + \frac{1}{2^s} + \frac{1}{3^s} + \frac{1}{4^s} + \dots$$

It is known that the distribution of primes depends intimately on the zeros of the zeta function.

The author goes into considerable detail concerning power series, and why they converge to a finite number, or not. This might not appeal to readers who have not studied these. Even less familiar are experiments approximating the zeta function by setting the infinite product (Euler product) to an infinite sum (Dirichlet sum). The diagram of the zeta function graph, noting points where it is zero within the critical strip, shows the non-trivial zeros in the middle of the critical strip. This is definitely mysterious to the uninitiated.

The discussions of field extensions to rings by E. Artin, A. Weil, H. Hasse, and P. Deligne become even more esoteric, as is operator theory, relating the non-trivial zeros of the Riemann zeta function to the eigenvalues of some Hermitian operator. Realizing that the author is attempting to provide a conspectus of many such attempts at proving, or disproving, the Riemann Hypothesis, most readers would be tempted to skip over these parts of the book.

The author John Derbyshire is a mathematician, linguist, and writer on many topics. His other book, *UNKNOWN QUANTITY*, is about the history of algebra. In *PRIME OBSESSION* he has created an interesting, enjoyable and informative book to enlighten the reader about the nature of the Riemann Hypothesis, and perhaps inspire someone to try and prove it.

Creating Undergraduate Research Opportunities Through Interdisciplinary and Intercollegiate Collaboration

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Abstract: *The Intercollegiate Biomathematics Alliance serves to bring students and faculty together different institutions to promote stronger education and research opportunities in biomathematics. One of their major ways of developing undergraduate research is through a research workshop. Projects are initiated by faculty inviting students to collaborate with them, and students are provided the opportunity to present their work at a national conference and publish in a peer-reviewed journal. We describe the details of the research workshop, and give insight into contributions to both the success and challenges of successful research with undergraduate students.*

INTERCOLLEGIATE BIOMATHEMATICS ALLIANCE

The [Intercollegiate Biomathematics Alliance](#) (IBA) was created in 2014 at Illinois State University to address the need for collaboration across institutions in the face of diminishing educational resources (Akman & Powell, 2018). Now, a state-recognized Center of Collaborative Studies, the IBA serves to bring together faculty and resources from multiple institutions to facilitate education and research in biomathematics. Institutional members of the IBA pay a fee based on institution size, and one of the benefits for students at member institutions is a fully funded research workshop and subsequent travel funding to present their research at a national biomathematics conference. This paper serves to describe the IBA Cross-Institutional Undergraduate Research Experience (CURE) and report on research projects that have initialized during the workshop. In following years, student and faculty participants will be tracked and surveyed to better understand the impacts the program has on developing future plans of students and how the workshop can better serve the needs of the participants.

CURE WORKSHOP DESCRIPTION

The CURE workshop takes place in early June each year. This time of year is chosen to avoid inhibiting students from engaging in a new project due to the stress they face during the academic year. The research that grows out of collaborations started at the workshop is intended to take place over the summer and into the following academic year. IBA institutional member students

and faculty attend the workshop free of charge (travel, food, lodging covered) but there is no direct compensation given by the IBA to the students or faculty for engaging in summer research. Faculty may choose to compensate the students if they have alternative funding sources to support undergraduate research. Non-IBA members are able to attend, but must pay a workshop registration fee and provide their own travel and lodging funding.

Faculty research talks are the foundation of the research collaboration weekend. Faculty mentors give 40-60 minutes talks on research they are currently interested in developing and how students can get involved in the research. The topic may be an continuing project for which the faculty would like to recruit more student involvement or a new project faculty would like to explore with motivated students. When faculty are unable to present in person, they present via video conference. After all faculty presentations, open time is given for students to talk to all presenters, in person or remotely, to discuss engaging in the research presented. This model benefits faculty who would like to involve students in their research by providing a wider array of motivated students. By expanding beyond drawing from just their home institution, where student interest may not coincide with the faculty area of expertise, faculty are able to connect with students who are truly interested in their work. By sharing faculty resources, students can identify a project that is of specific interest to them and are not limited to only the interests of faculty at their school. For example, students from a small school with limited computer science faculty were able to use their programming skills on a neural network research project with faculty from a much bigger school, an opportunity that would not have been available to them at their home institution. In return, faculty from the small school mentored students without as much computing background on development of epidemiology models, not requiring as rigorous of computing methods as the neural network project.

If faculty and students who embark on a project together are not from the same institution, video conferencing tools are available through the IBA, and additional travel funding for students to meet with the faculty mentor may be available. As the workshop has evolved, faculty are encouraged to share introductory literature before the workshop so students can read about potential research projects for which faculty will give presentations.

The workshop also strives to expose students to the entire research process including computational tools and scientific writing. Therefore, the weekend includes a hands-on presentation on a scientific computing tool such as Mathematica or R as well as exposure to the process and tools for writing in mathematics.

The workshop's primary purpose is to develop collaborations both among students and between students and faculty. In order to facilitate increased conversation between students from different institutions, the weekend involves scheduled social activities including an opening ice-breaker activity, a student v. faculty soccer match, and a night of bowling and pizza. We find scheduling these social events allows students to connect in a meaningful way and allows them to develop deeper relationships with other highly motivated students.

The goal is that at the conclusion of the workshop, students will decide on a research project and communicate with the faculty member directly through the summer and subsequent school year. Students are provided travel funding to present the status of their work at the Biomathematics and Ecology Education Research (BEER) Symposium in October of the same year and encouraged to submit a manuscript to the biomathematics journal *Spora* within a year of their participation in the workshop, with reduced open access publication charges.

APPLICATION PREOCCESS

The workshop initially was open to all who wanted to participate, but we found some students did not have the appropriate background to be able to meaningfully engage in research. In addition, financial resources are limited to fully fund student participation, therefore, starting in the second year, the workshop currently limits participation to 10 student participants chosen through an application process but the number may increase as more institutions join the IBA. Students submit their transcripts and a short narrative describing their interest in the program. The only coursework requirement is completion of Calculus 1 by the time of the workshop. In order to avoid students not showing up for the program after committing, a fee is imposed for students who do not participate after a given withdraw date. Faculty from students' home institutions are asked to write a letter of support including a commitment to provide in person follow-up for students who engage in research with faculty from other institutions. Preference is given to students early in their academic career who have not had alternative opportunities to engage in undergraduate research. The students who apply are generally encouraged by faculty at their home institution who think the student will benefit from engaging in research. Students often do not know about research opportunities and the workshop allows them to get involved in research early in their academic careers, often before they would have the requisite coursework for a competitive National Science Foundation sponsored Research Experience for Undergraduates (REU). The Acceptance rate to the workshop are high for qualified students, whereas acceptance rate for paid summer research at an REU is usually below 10% (Beninson, Koski, Villa, Faram, & O'Connor, 2011). Additionally, unlike a traditional REU, the students are not required to be US citizen or permanent resident.

STUDENTS RESEARCH PROJECTS EXAMPLES AND EXPERIENCE

Examples

Project A: Epidemiology model of a wildlife disease

Two biology students participated in this study and they were equally responsible for a review of relevant literature. One student focused on studies documenting the spread of the disease including transmission modes and latency period, including standard birth and death rates for both healthy and diseased animals. The other student focused on the immunology of the disease and potential containment strategies including recent vaccination efforts. Both students contributed to the development of the mathematical model with the faculty mentors based on their discoveries in the

literature. One student did the majority of the numerical computations with the assistance of a faculty mentor and both students participated in manuscript writing with editing done by a faculty mentor. This project won an Outstanding Undergraduate Research Award for the manuscript and presentation at the Biomathematics Ecology Education and Research Symposium.

Project B: Immunology model connecting *in vitro* and *in vivo* studies

One biology student and one biochemistry did an extensive literature review of both *in vitro* and *in vivo* studies and provided guidance on important parameters to consider when considering *in vitro* to *in vivo* extrapolation and inconsistencies in studies done in each setting. The faculty mentor and students developed the mathematical model together and the majority of the numerical computations were done by the faculty mentor. The manuscript writing and editing was shared equally between the students and faculty mentor.

Experiences

Students who voluntarily elect to participate in research are often high-performing students who demand excellence of themselves in their academic work. Spending a vast amount of time reviewing literature that is not familiar to them allowed students to be more comfortable in admitting a lack of knowledge of a particular field. The discouragement of not initially understanding material was transformed to growth in the eventual understanding of a foreign topic. This growth allowed students more confidence with traditional course material that they initially struggled with and found challenging to master. Research also forced the students to think more creatively than their regular courses, since there was no roadmap to a correct answer. Considering all the factors that may not only be important in a biological system, but are also measurable, is a challenging task and requires creative thinking to determine how exactly to address relevant factors in a mathematical model. Students had to venture outside of what they had learned in their math courses to come up with appropriate ways to represent the myriad of factors they were reading about. For example, in Project A, the students noticed through using the manipulate function in Mathematica, the system was much too sensitive to the birth parameters. They reconsidered the parameter ranges for the number of offspring per breeding cycle and percent of animals breeding. They were unable to stabilize the population with modified parameter ranges and found their original values consistent within the literature. They ended up deciding to add a carrying capacity term in order to keep the population values within acceptable ranges for what was reported in the literature. In Project B, *in vitro* experiments often have an initial incubation period, after which a washing of the medium occurs. The students wrestled with how to account for the washing including considering a two-part model. The analysis of a two-part model became cumbersome so the students decided to include a step function turning different parameters on and off based on the initial incubation period. Through the time they spent grappling with how to appropriately represent the biological system mathematically, eventually, the students became better experts than the faculty in the research topic due to all the time they spent reviewing the literature and became more research colleagues than mentees to the faculty mentors.

The workshop and research experience has also influenced students' academic and career plans as well as personal growth. A transfer student, who had not connected with other students previously, found college friends for the first time at the workshop. Additionally, a highly introverted student who rarely interacted with peers in the classroom became animated and social with peers interested in similar pursuits. The decision to engage in research allows students to gain a better understanding of what graduate school may entail for them. While some may decide research is not a future direction they would like to pursue, many find it a valuable experience to solidify their decision in future career plans. After participation in research, one student from Project A changed career goals from attending a Physician Assistant program to pursuing an MD PhD for research in infectious disease. A student from Project B was unsure of post-graduation plans prior to participating in the workshop, and realized research is an important and enjoyable career path and is now pursuing graduate options in both pathology and medicine.

SUCESSES AND CHALLENGES

In its first two years, the CURE workshop had 28 student participants and 16 distinct faculty presenters, many faculty presenting in multiple years. Student academic backgrounds have included mathematics, biology, and computer science. Of the students whose research started at the CURE workshop, 11 have presented at the BEER Symposium, and 3 have published in Spora. Additionally, one of the CURE workshop participants won the Outstanding Undergraduate Research award at the BEER Symposium. Research initiated at the workshop has spanned from epidemiology models including water borne illnesses to neural networks and genetic algorithms. While the workshop has led to many connections that produced meaningful research, challenges still present themselves when engaging in research with undergraduate students, especially in when mentoring is done remotely. The biggest obstacle is always student follow through. Students may leave the workshop with every intention of following through on research through the summer, but often other activities take priority, especially work, since the research is unpaid. For students who are active participants, remote mentoring provides two unique challenges. First, for projects where data collection is involved, the student is often unable to participate in the data collection since they are not present in the data collection location. Although they may be of assistance in the analysis of the data, this can lead to secondary challenge in that fee-based computing programs may not be available to all research participants. Students may have access to a different program than their faculty mentor, requiring purchasing of the software by one party or analysis to either be done by one participant or be done in an open access software program. With the growing capabilities of open access programs, computing program boundaries will lessen, and the IBA is considering additional ways to resolve this problem through licensing agreements. Finally, students wishing to have their research be part of a senior capstone project requirement must be careful to satisfy the requirements of the project as set forth by their home institution. This can provide challenges in mentoring, especially for faculty mentors at another institution who will not know the specific requirements for completion of a capstone project. Students must be diligent in

appropriately communicating their intentions in an overlap between CURE initiated research and graduation required capstone projects.

CONCLUDING REMARKS

Overall, the CURE workshop has successfully led to many fruitful collaborations between students and faculty wishing to engage in joint research projects. It provides an opportunity where students may have none to explore a world outside of the academic classroom to delve further into their field of interest. While not a paid research position, the program is much more accessible for students of all backgrounds than an REU and allows students to engage in research who would not have otherwise thought it possible. The program strives for continued improvement in satisfying the needs of participants and help them overcome the challenges that inhibit research projects from flourishing.

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