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The AfterMath: A Culturally Responsive Mathematical Intervention to Aid Students Affected by Natural Disasters

Brianna Kurtz
University of Central Florida

THE AFTERMATH: A CULTURALLY RESPONSIVE MATHEMATICAL INTERVENTION TO AID STUDENTS AFFECTED BY NATURAL DISASTERS

by

BRIANNA KURTZ
B.S. Vanderbilt University, 2004
M.S. University of Nevada, Reno, 2007

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ABSTRACT

On September 20, 2017, Hurricane Maria struck the island of Puerto Rico. The damage was extensive, and many people found themselves to be natural disaster refugees. As a result, schools in Central Florida saw an influx of new students who had their educations interrupted by the disaster and now were resuming school in a new language of instruction. These students not only faced linguistic challenges but also academic differences due to the high prevalence of poverty and the effects of neocolonialism in their previous schooling. This mixed methods study implemented an intensive intervention in probability to aid students in developing mathematical understanding and forming meaningful connections. Student participants, who had been affected by Hurricane Maria, were now attending a public high school and were paired one-on-one with a bilingual, mathematically high performing student mentor to complete culturally responsive, bilingual probability tasks. Data collection occurred over the course of six weeks in fall 2019. Both mentor and mentee students participated in focus group interviews, and the mentees completed a probability pre-test and post-test. Student participants were found to have statistically significant increases in the understanding of probability concepts when comparing pre-intervention and post-intervention results, with the understanding and usage of the multiplication rule showing the most significant improvement. Both mentors and mentees reported feeling a stronger sense of unity and belonging post-intervention as well as improvement in bilingual academic vocabulary. With the impact of natural disasters on the rise, implications of this study include its adaption to respond to future displaced students as they resume schooling post-interruption in Central Florida and beyond.

From the aftermath of hurricanes, recession of floodwaters, and ashes of wildfires, students rise across the globe, rebuilding their lives and resuming their education. This dissertation is dedicated in their honor. May your thirst for knowledge never be interrupted.

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LIST OF ACRONYMS

AP	Advanced Placement
ASVAB	Armed Services Vocational Aptitude Battery
CCSSM	Common Core State Standards for Mathematics
FEMA	Federal Emergency Management Agency
IFRC	International Federation of Red Cross and Red Crescent Societies
MAFS	Mathematics Florida Standards
NGO	Non-Governmental Organization
PRCS	Puerto Rico Core Standards
SIFE	Student with an Interruption in Formal Education
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNICEF	United Nations Children’s Fund
USAID	United States Agency for International Development

CHAPTER ONE: INTRODUCTION

When considering all secondary school subjects commonly taught in the United States, a student's performance in mathematics courses is the best predictor of likelihood to continue education beyond high school (Scott & Ingles, 2007). However, in areas plagued by educational interruptions, there have been multiple studies showing mathematics education specifically to be harshly impacted. In the United States and around the globe, a steady increase in the incidences of natural disasters, such as floods and storms, has been noted, with property losses now triple what they were thirty-five years ago. These losses lead to interruption in everyday life, including in the workplace and at school (Hoeppe, 2016). In Bangladesh, where schools in flood and cyclone-prone areas have frequent closings for more than twenty consecutive days, dropout rates were found to increase by 3% and mathematical competency results significantly lowered (Felices Sanchez, 2013). Similar drops in mathematical competency post-natural disaster have been found in Madagascar (Marchetta, Sahn, & Tiberti, 2018). In a large-scale study across multiple Caribbean nations and territories, mathematics achievement scores were found to suffer post-hurricane at a significantly higher rate than any other subject. This was hypothesized to be due to the guidance needed for mathematical learning that was not commonly available in the home setting (Spencer, Polachek, & Strobl, 2016).

Instead of pursuing avenues to aid students in mathematical achievement upon their return to school, literature and reports instead have often shown school districts requesting education-related waivers for students. For example, in the case of the Hurricane Harvey disaster zone in Texas in 2017, the elimination of multiple mathematics accountability tests was enacted for fifth and eighth grade students across the 47 counties under the Presidential Disaster

Declaration (Morath, 2017). More recently in the Florida Panhandle, multiple school districts sought disaster-related waivers requesting their school letter grades not be lowered due to poor mathematics test results. Officials stated that the reasoning for this was not only due to the interruption itself, but because of the absorption of new students from lower socioeconomic areas within Florida who became displaced by Hurricane Matthew. The superintendent of Gulf District Schools Jim Norton, stated in response to the influx of students who came from the Bay District Schools, "Those students were not the students we started with, who we worked hard with for two or three years to take the [Florida Standards Assessment]" (Croft, 2019). If natural disasters were truly rogue phenomena that struck once and caused a quick school interruption, then the approach of calling for waiver due to unique, isolated, unforeseen circumstances could be understandable. However, this is not the case.

According to the Internal Displacement Monitoring Centre (IDMC), in 2016 alone, 23.5 million people found themselves newly-displaced due to weather-related phenomena, adding to the total of 195.7 million since 2008. The vast majority of these displacements were internal to the country of the natural disaster (IDMC, 2017). Often, these displaced persons are not exiting the educational system from which they were enrolled pre-disaster but rather are part of a growing group of young people who are trying to continue their educational pursuit despite interruptions that can range from days to years and, in locations with frequent natural disaster activity, interruptions can occur throughout a student's education pursuit (USAID, 2014). In March and April of 2019, Mozambique was hit back to back by Cyclone Idai and Cyclone Kenneth, respectively, with Kenneth being the strongest cyclone to affect the country to date (UNHCR, 2019). As of July 2019, 72,825 children were being served by United Nations

Childrens' Fund (UNICEF) in 356 temporary learning spaces (UNICEF, 2019a). However, UNICEF has been able to provide assistance to just a fraction of those affected, as current estimates cite 335,132 displaced students from 3,504 classrooms (UNICEF, 2019b).

Natural disasters such as hurricanes/cyclones, earthquakes, and severe flooding are known to have economic and emotional impacts on a country's citizens, but they also are often accompanied by interruptions to the educational system (USAID, 2014). Students may be out of school due to the immediate impact of the natural disaster but, even long after the event has occurred, school buildings are often used as shelter sites for those most affected by the occurrence (e.g., Pine, Marx, Levitan, & Wilkins, 2003). Therefore, it may take additional, unpredictable amounts of time for students to be instituted back into their building. For example, in the aftermath of Hurricane Irma in September 2017, one Central Florida elementary school was designated as the shelter for those affected by homelessness, mental illness, and drug addiction. Due to short staffing and proper mental health resource supervision, the elementary school suffered thousands in damage from the clientele during the storm, and students were delayed in their school attendance for an additional week beyond the rest of their district's return (Harrison, 2017).

In order to combat the interruptions to education accompanying disasters during the time of recovery, several programs have been adopted as the go-to standards of practice. One of the main programs used globally is run through UNICEF and is called the "School-in-a-Box" program. The School-in-a-Box initiative was originally developed for use in Somalia and Afghanistan but saw its first full implementation in the mid-1990's when the Rwandan refugee crisis had reached a critical point and millions of children were displaced and out of school

(Barricklow, 1995). UNICEF created a box of supplies for teachers to be able to establish make-shift classrooms and continue the educational process for affected children. A quarter of a century later, the program has been used on every continent in disasters of political and, even more often, a weather-related nature. The goal of UNICEF is to reestablish education within 72 hours of a disaster. The kits now contain supplies for a classroom of 40 children and include instructional aids, manipulatives, supplies and, depending on the severity of the disaster, curriculum (UNICEF, 2017).

The United Nations' Millennium Development Goals (MDG's) recently closed and were replaced with a focus on the Sustainable Development Goals. With the MDG's, the largest focus of the educational goals was achieving global literacy. Due to this, funding provided by governments to support programs run primarily through multilateral and non-governmental organizations (NGO's) have been focused on issues of education in terms of reading and writing (United Nations, 2015a). As these organizations have also been responsible for helping to achieve educational continuity in the aftermath of disasters, much of the supplies, curriculum, and personnel have focused on students maintaining gains in literacy (Moriarty, 2018). For students in long-term and short-term non-traditional educational settings, this means that mathematical learning experiences are being lost globally for thousands who are affected by situations beyond their control.

For those students who have experienced these interruptions, had non-traditional temporary educational settings, and are now returning to formal schooling, many challenges arise. Although some students do return to school in the location in which they lived originally, many attend new institutions. In the case of the Haiti earthquake that devastated the island in

2004, most public schools did not reopen and, in fact, 90% of Haiti's residents who are in school today attend private schools, mostly for-profit institutions (Vallas, 2014). After Hurricane Katrina caused havoc upon New Orleans, the existing public school system was largely dismantled in favor of a charter system and, though students may have returned to school, it was not to the school or teachers they had known (Perry, 2006).

For students whose homes have been devastated to the extent that they have no choice but to emigrate, the challenges are systemically even more pronounced. First, one must consider the challenges of the previous temporary schooling. Students have often been grouped together based on proximity instead of ability or even grade level and they would have experienced curriculum interruptions and thus received instruction that may or may not be directly in line with their previous educational trajectory. Now, upon entering a new institution, they often find themselves behind and this frustration has been seen to lead to an increased dropout rate, especially when issues of language difficulty are a concern (Fry, 2003).

In order to address this issue, several key strategies have emerged. First, having a supportive staff that is bilingual and bicultural has been shown to help bridge the gap and increase achievement in students who are entering a school that did not previously have a similar language and/or culture. Newcomer programs to develop a supportive cohort have been found to be impactful (e.g., Dover & Rodríguez-Valls, 2018; Seilstad, 2018). Furthermore, in lieu of students being placed in developmental classes, an increase of "sheltered instruction" has been found to have profound positive impacts on student learning and confidence (Spaulding, Carolino, & Amen, 2004).

This case of transition and displacement is one that many students from Puerto Rico have found themselves in after Hurricane Maria struck on September 20, 2017. In the year since the event, 263 schools closed permanently and another 270 absorbed the displaced students from those schools (Ujifusa, 2018). This has led to many Puerto Rican nationals to move to the mainland of the United States and resume education, particularly in the state of Florida, which gained thousands of refugees from October 2017 through February 2018, as shown in Figure 1.

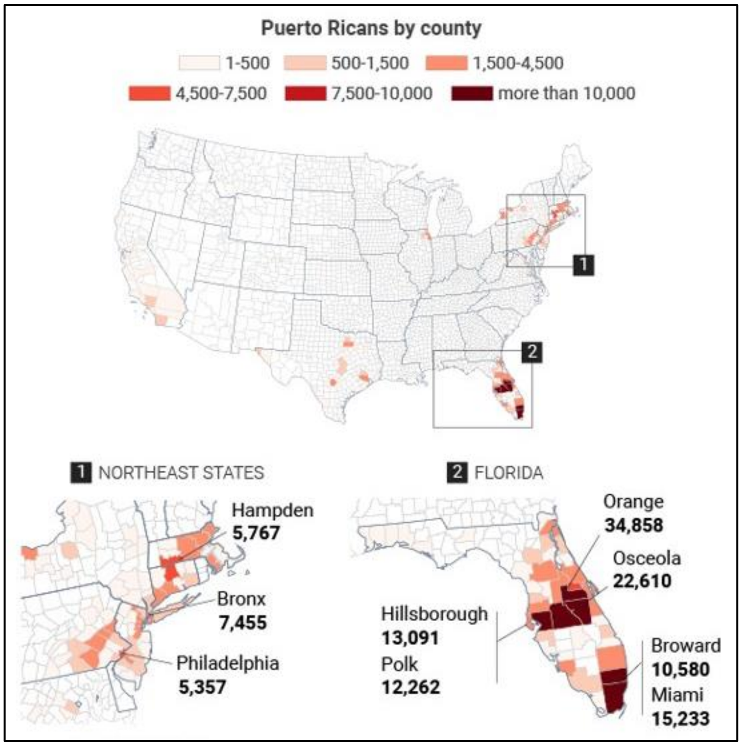


Figure 1: Immigration from Puerto Rico post-Hurricane Maria, October 2017 – February 2018. From Mapping Puerto Rico's hurricane migration with mobile phone data, by M. Echenique & L. Melgar, 2018, https://www.citylab.com/environment/2018/05/watch-puerto-ricos-hurricane-migration-via-mobile-phone-data/559889/. Copyright 2018 by Luis Melgar. Reprinted with permission (Appendix A).

Although some Hurricane Maria refugees have returned to Puerto Rico, many have chosen to remain in the mainland United States to seek the educational and economic opportunities that are now more diminished in the island territory than they were before the hurricane. Currently,

91.9% of students attending school in Puerto Rico are Free and Reduced Lunch eligible (Ed.gov, 2019). Furthermore, in 2012, the last time data were made publicly available by the United States Department of Education, Puerto Rico had a high school graduation rate of sixty-two percent, approximately twenty percent lower than the mainland United States, and in terms of mathematical achievement, ninety-four percent of students scored below the cutoff for the basic achievement level on the National Assessment of Academic Progress (NAEP) (Sparks & Superville, 2017). One outcome of this migration is that the state of Florida has a responsibility to its new students to ascertain their right to an equitable educational experience in the public school sector, provide language support to the newly arrived students, and, in particular, to increase their achievement in mathematics education.

Problem Statement

Public schools in Florida are now faced with thousands of new students who not only have been out of school for various lengths of time due to interruption from Hurricane Maria, but also face the challenge of entering into a school where the primary language is not their first language. Though learning any subject in this scenario has challenges, the learning of mathematics poses a unique challenge as, in times of interruption, it is one of the subjects most frequently not continued at home and through independent study during the transition (Spencer, Polachek, & Strobl, 2016). Within the content domains of mathematics, topics regarding probability knowledge, which connect to ideas in both algebra and statistics, are of a particular interest as the language mastery required to develop understanding of the concepts in these content domains is uniquely complex due to the lexical ambiguity of many terms in probability as well as the sentence modifiers used in most written probability problems, as will be discussed in the literature review. Therefore, there is a need for an intervention designed to aid in the

mathematical success of marginalized students who have been impacted by Hurricane Maria and have become involuntary immigrants in mainland United States schools.

Purpose of the Study

The purpose of this research study is to provide an intervention to students who have entered the mathematics classrooms of a Florida high school by engaging them in a newcomer program cohort where they will be paired with same-language student mentors to determine if this results in greater understanding of topics involving probability.

According to the Federal Emergency Management Agency (FEMA), Florida has the fifth-highest number of disaster declarations in the United States since data collection began in 1953 (FEMA, 2019). When Hurricane Maria hit Puerto Rico, seven of the top ten counties in the United States receiving the most hurricane refugees were in Florida (Echenique & Melgar, 2018). Therefore, due to Florida's high population of immigrants from Hurricane Maria and high frequency of natural disasters itself, it is an ideal location for this study in order to aid students who have had their education disrupted by natural disaster and are now facing challenges in a new learning environment.

Research Question and Significance of the Study

In order to investigate mathematical understanding after an interruption in formal education, the following research question was posed:

- *How does a culturally responsive, mentor-guided mathematical intervention support the understanding of topics in probability for students with educational interruptions caused by natural disasters?*

Although the literature base and quality of studies being conducted on education in emergencies is increasing and improving, the bulk of currently available information is in the

format of reports by multinational and non-governmental organizations such as the United States Agency for International Development (USAID), the World Bank, the UNICEF, the United Nations Scientific, Educational, and Cultural Organization (UNESCO), and the International Federation of Red Cross and Red Crescent Societies (IFRC). Academic studies are new to the literature as it becomes increasingly feasible to monitor populations who have been affected by natural disasters. To that end, the main sources of literature regarding interrupted populations involves the education of political refugees. Those affected by natural disasters are not as frequently studied, partially due to the fact that the time of the interruption fluctuates so greatly and the tracking of those students is challenging. However, approximately 160 million people every year are affected by a natural disaster in some capacity (World Health Organization, 2018). With such a large population finding themselves in this scenario, educational interruptions are a real and ongoing concern.

Probability was chosen as the mathematical content of focus as it is a content domain that transcends multiple grade levels and does not necessarily rely on complex algebraic prerequisite knowledge in order to develop understanding. However, many probability exercises originate in word problem scenarios. If a student is coming into a school as a displaced natural disaster refugee, there is the possibility that they are experiencing a change in language of instruction. This can lead to the need for more bilingual and bicultural considerations to aid in the reading and the contextual understanding of probability problems so that the mathematics is more accessible (Orosco, 2014). Therefore, the concept of probability can be used not only to strengthen mathematical understanding but also to make gains toward English language fluency.

Currently, the literature regarding best practices in education after interruptions due to natural and political disasters is limited. The majority of studies that exist are in literacy education and usually focused on refugees from political disasters. With regards to mathematics-related studies, they are far fewer in number, and after exhaustive search, the ones found were either focused on early grades mathematics or on algebra. Thus, there is a gap in the research of the important and growing marginalized population of students who are affected by natural disasters when it comes to statistics in general, and probability in particular. Without a basic understanding of probability knowledge, students will later struggle to be able to make statistical inferences (Franklin et al., 2007). These students affected by interruption bring to the forefront a unique issue of equity within mathematics education. The National Council of Teachers of Mathematics (NCTM) has made a pointed call to increase access and equity in mathematics and has specifically recognized that "current reform efforts… are unlikely to address and alleviate equity concerns unless they also address and dismantle the conditions and systemic structures that stand as barriers to the creation of positive mathematical experiences for students – particularly those who are not experiencing success in mathematics" (NCTM, 2018, p. 16). It is clear that a specific intervention may be needed to aid these students in their mathematical success.

Summary

For those who are affected by natural disasters, the continuation of education can be a challenge, particularly in mathematics. When considering the population that is displaced long-term by a natural disaster, adjustments must be made to the educational practices of a new homeland and this often comes with unique challenges, including changes in the language of education and catching up after an extended period of being out of school due to the disaster

itself. In the secondary mathematics classroom, statistical content in general, and probability in particular, provide a great challenge for students who are second language learners due to the fine nuances of language in the problems themselves and cultural contexts that may be unfamiliar to the immigrant student. Hurricane Maria has brought thousands of students to schools in the state of Florida, and special consideration must be given to the mathematics education of this marginalized population. In order to discern the method of intervention to best serve this group of natural disaster survivors, key research in the context of mathematics education in the areas of education in emergencies, bilingual education, culturally responsive curriculum, peer mentoring and cohort education, and probability will be thoroughly reviewed in the next chapter.

CHAPTER TWO: LITERATURE REVIEW

Introduction

In this chapter, the multiple variables that impact natural disaster refugee students who are trying to learn mathematics in general, and probability in particular, will be discussed. At the forefront, these students have been impacted by a major natural disaster that has caused an interruption in their education, in this case a hurricane. The way that educational policies have shifted in selected American and island locations following a natural disaster will be briefly described, then key literature on mathematics education in emergencies will be discussed. As there are limited studies on mathematics education in emergencies, all available studies from refereed journals on the impact on mathematics education in emergencies are presented in this review.

Students arriving from Puerto Rico to the mainland United States have the additional challenge not just of being displaced internally, but this forced immigration takes also involves a change in the language of instruction in the mathematics classroom. Studies from across the globe are discussed here examining impacts of language of instruction in the mathematics classroom and a comparison of approaches that are bilingual, multilingual, and translingual in nature. The purpose of this discussion is to set the stage for the necessity of an intervention that includes elements of students' native tongue in order to aid their mathematical learning. As there exists a plethora of studies regarding language and mathematics, key journals in mathematics education, including the *Journal for Research in Mathematics Education*, *Educational Studies in Mathematics*, and *Mathematical Thinking and Learning,* were exhausted to describe the current state of research on this topic within the past decade.

When considering mathematics and language, one area of particular concern is that of statistics, and in particular, probability. As many probability problems are contextually-based and require solid knowledge of the language in which they are being presented, this can add an extra layer to knowledge attainment. Key studies on probability learning and developing conceptions within probability and statistics are cited as well as a history of how key probability content are presented within the Common Core State Standards.

Students coming from Puerto Rico additionally experience culture shock. The key studies regarding culturally relevant mathematics, from the beginnings of ethnomathematics to current research are reviewed. This serves to give reason as to why, within the intervention to be conducted, the topics of choice are so important as a sense of cultural relevance not only in the Latino/@/x and Caribbean sense but in the realm of unification among the students in the experience of coping with a natural disaster.

As students in the intervention were attending schools in Puerto Rico before Hurricane Maria struck, the next section discusses issues plaguing schools on the island, which are rooted in poverty, language, and the challenges of a neocolonial education, whereby factors such as economics, politics, and culture strongly influence the pursuit of formal learning. Mathematical performance within the Puerto Rican schools will be shared and compared to the United States and more broadly in order to obtain a clear picture of the educational situation of students prior to their entry into the mainland United States schooling environment.

Finally, the theoretical framework of intersectionality theory will be introduced as the overarching theory to guide this study. Though intersectionality originated from feminist theory (Crenshaw, 1989), applicability in educational research will also be explored. The *AfterMath*

Framework, developed for this study in particular, will be introduced to describe how student mathematical learning lies in the intersection of the various unique circumstances that have affected these natural disaster-displaced students, including language, poverty, and neocolonialism.

Education in Emergencies

When one considers the impact of natural disasters, particularly hurricanes, on educational attainment and achievement, Hurricane Katrina is one of the most widely studied events. Hurricane Katrina hit the Gulf Coast of the United States in August 2005 and subsequently wreaked havoc on the region, with one of the main areas of damage being New Orleans Parrish in Louisiana. The devastation that hit New Orleans exacerbated an already impoverished area with socioeconomic difficulties. New Orleans has a poverty rate of 25.4%, as compared to the United States rate of 11.8% (United States Census Bureau, 2018). Natural disasters disproportionally affect those who are impoverished (Vallas, 2014). This can lead to far greater challenges in reestablishing education when the socioeconomic structure for development is not solid. The establishment of the charter system in New Orleans in place of the previously existing school system in New Orleans Parish was met with mixed feelings, particularly by the teachers who had been teaching in the system for much of their careers (Alzahrani, 2018; Frazier-Anderson, 2008; Lincove, Barrett, & Strunk, 2018).

The New Orleans case is not an isolated incident of educational policy change post-disaster. Such policy changes are seen repeatedly with small island nations post-disaster, especially in situations where damages total more than 1% of the nation's annual gross domestic product (GDP) (World Bank, 2010). In the island nation of Vanuatu, one of the most susceptible

nations in the world to natural disasters, education recovery after Cyclone Pam which caused damage to 100% of the country's schools has been a particular challenge (McCormick, 2016; United Nations, 2015b). The government then seized this as an opportunity to implement educational reform, namely reinstituting mother tongue language education into the island's schools as a measure to self-identify away from the colonial education which had held the island nation for so long (McCormick, 2016; Willans, 2017). Although the results so far have been mixed in terms of effect and best practices, the idea that a devastating natural disaster can give way to educational innovation is groundbreaking. As neighboring Tonga has now also undergone cyclone devastation in March 2018 and a subsequent temporary education provided by the UNICEF School-in-a-Box program, similar educational reforms are predicted to be considered there, particularly with issues of gender equality (Roy, 2018).

Mathematics Education in Emergencies

When considering academic achievement specifically within mathematics after a natural disaster, the research has been fairly limited. In a large-scale study in the Caribbean, though, it was noted that mathematics test scores of students in hurricane-impacted areas saw statistically significant decline if a hurricane struck during the academic year. If, though, the hurricane hit outside of the academic year, there was no noticeable effect on mathematics. This was hypothesized to be due to the importance of the classroom teaching aspect of mathematics education as compared to English, where families reported feeling more comfortable supplementing students in the home setting while waiting for formal schooling to resume (Spencer, Polachek, & Strobl, 2016).

In the United States, a comprehensive study incorporating nearly ninety percent of public schools in the state of Mississippi found negative significant effects on the mathematical

achievement of fifth grade, eighth grade, and Algebra I state test scores for students in the two academic years following Hurricane Katrina when compared to the two academic years before the hurricane event. This effect was seen even more significantly in the highly impoverished areas of Mississippi, where the fifth grade and Algebra I scores of those living in areas with greater poverty and closer to the center of impact had a greater decrease in scores than those without the combination of socioeconomic hardship and proximity to the event (Lamb, Gross, & Lewis, 2013).

Mathematics education in the world of refugee camps has seen some study, but often the issue of lack of supplies is so severe that mathematical achievement is not of focus. In one particular study of Zimbabwean refugees in South Africa, the greatest recommendation was to have enough books to go around so students had tools from which to learn mathematics and, if this was not a possibility, to conduct schooling in shifts (Pausigere, 2012). Similarly, in Syrian refugee camps, some solace to a lack of supplies has been found in the creative use of cell phone apps to aid learning, including in science and mathematics (Schwartz, 2017). However, research regarding mathematical achievement gains (or losses) is scarce and, at this time, is giving way to the supply demands of these vulnerable populations.

However, students who are displaced in their education, whether it be by natural disasters or political disasters causing a refugee status, are not necessarily at a state of permanent disadvantage. Although there has been a negative correlation found between the length of time spent out of school after a disaster and academic achievement, it has also been found that a positive mitigating factor to this phenomenon is that if the displaced student is enrolled at an institution where students are higher performing than the school in which they were enrolled

prior to the natural disaster, the student tends to remain on a similar track in their academic gains as if the interruption had not happened (Pane, McCaffrey, Kalra, & Zhou, 2008). This gives hope that there are situations where students may academically overcome being displaced.

Issues of Language and Mathematics Education

Whether coming into the classroom as natural or political disaster refugees or as voluntary immigrants, students who are emergent bilingual face unique challenges when considering their mathematics education and mathematic achievement (e.g., NCTM, 2018). Over the years, students with language differences have been shown to have lower performances on assessments of mathematical knowledge such as national trend studies, college admissions examinations, and Advanced Placement (AP) examinations with results that are not dissimilar to results found among the socioeconomically disadvantaged or among marginalized racial groups (e.g., Abedi & Lord, 2001; Brow, 2005; Khisty, 1997; Tate, 1997; Secada, 1992). This has led to a growing body of research, especially in the past two decades, in the field of mathematics education centered on emergent bilingual students.

It has been argued, however, that a focus on learners with gaps in their achievement, such as has been the case with much of the literature on emergent bilingual students, can be harmful in normalizing the low achievement of these groups and thus creating a further sense of marginalization (Bartolomé, 2003; Guitérrez , 2008; Lee, 2002). Though much research has been conducted about the current circumstances of emergent bilingual students in classrooms, less mathematics education research focuses on those students' experiences prior to entering continental United States classrooms (Barrett, Barile, Malm, & Weaver, 2012; Suarez-Orozco, Pimentel, & Martin, 2009). This lack of published research may cause the field to miss strategies and techniques that could help students as they work to master new language skills as well as the

language and content of mathematics (Guitérrez, 2008). Though certain studies have found an advantage in positive peer interethnic interactions in increased language mastery for mathematical use to have profound effects (e.g., Norén, 2015; Barrett, Barile, Malm, & Weaver, 2012), there are a variety of factors to consider in terms of second and third language learners and mathematical achievement.

This notion of the benefits of bilingual and multilingualism in learning has led to the coining of the term *emergent bilingual* to describe those in the process of second language attainment. Coined by Garcia in her seminal work *Emergent Bilinguals and TESOL: What's in a Name?*, Garcia makes the case that the labels of students as English language learners (ELLs) or Limited English proficient (LEP) focuses on a perceived deficiency rather than potential in language development (2009). Thus, in this study, the term emergent bilingual will be used in describing students for whom English is not their first language, acknowledging that in some cases students could also be an emergent multilingual. The term emergent bilingual recognizes students' knowledge of more than one language as an asset to their learning.

Bilingual and Multilingual Learners of Mathematics

There have been multiple studies through the years supporting the notion that bilingualism correlates with strong mathematical performance (e.g., Clarkson, 1992; Dawe, 1983; Yeh, 2017). In an Australian study, students who were assessed as fluent in two languages had higher scores in general mathematical knowledge, word problems, and number competence than peers who were only strong in one language or were strong in one and attempting to learn another (Clarkson & Galbraith, 1992). Another case from the United States considered 157 Spanish-speaking first grade emergent bilingual students in the southwestern part of the country who were experiencing difficulties in mathematics. It was found that upon follow-up that as

these students learned English and grew in their bilingual skills into the second and third grade that they also saw a rapid decrease in their mathematical difficulties. This was attributed to a correlation between the growth of the executive component of working memory used in language attainment and the cognitive capabilities necessary to overcome mathematical difficulties (Swanson, Kong, & Petcu, 2018).

When learning a new language, even basics such as number representation and word meaning can be vastly different. Comparing Spanish and Basque-speaking students, for example, due to the differences in how numbers are expressed, young children showed different performance in their ability to gather an amount of objects to make a set versus counting the number already present in a set (Domingo Villareal, Miñón, & Nuño, 2011). These linguistic differences should not be dismissed as minor. In fact, these can have lasting impacts when there is a later switch in language of instruction.

There are complexities with language and the learning of mathematics that must be considered, however, when the native language of a student is not considered “major” in the Western world. The mathematics that has been deemed the most respected and promoted through standardized assessments such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) has primarily been Eurocentric. Here lies the problem that standardized test scores only approximate student knowledge and do not take in to account the whole realm of student mathematical understanding, especially on the conceptual level (Tarr et al., 2013). For the bilingual or multilingual student where multimodality could be used to assess learning, the design of these international tests occur in such a way that conceptual understanding is not the assessment focus in the way

procedural knowledge has been (Fernandes, Kahn, & Civil, 2017). Additionally, mathematics as assessed through the TIMSS and PISA has been largely Eurocentric mathematics and largely ignores indigenous knowledge bases. Many languages do not have the complexity or vocabulary to correspond to Eurocentric mathematics, thus a language switch needs to take place for learning in this realm. Though some research has shown student creation of terms in order to combat this (e.g., Planas, 2014), usually the mathematical vocabulary in the dominant language is the focus. Some countries, such as New Zealand, are making a large push for the inclusion of indigenous mathematics and tying in cultural roots and native tongue into lessons (Meaney, Trinick, & Fairhall, 2013). However, this is not the case globally and more of the exception than the norm.

In the United States, 80% of emergent bilingual students are native Spanish speakers. This creates the need for a focus on bilingual education and techniques of assessment of learning in our country. However, this is not necessarily the same situation found worldwide. In Sub-Saharan Africa, multilingual classrooms often occur to take into account the many tribal languages. As an example, in the *Journal for Research in Mathematics Education*, Phakeng and Moschkovich (2013) published an open dialogue between them comparing language of instruction practices in South Africa and the United States. In much of sub-Saharan Africa, lessons are taught in a national language or native tongue through the equivalent of grade 4 or 5 in the United States, and then a switch to all English is made in the following year. Although English has been used as a second language in the classrooms leading up to this point, this full switch is a struggle for students. As a result, many classroom teachers end up favoring a behaviorist approach as opposed to constructivism because students and even teachers do not

have the language mastery to have the intricate discourse found in the constructivist classroom (Phakeng & Moschkovich, 2013).

Phakeng and Moschkovich compared their nation's policies on language of instruction and issues of language within mathematics education with Moshkovich's previous experimental research in providing techniques in bilingual education that help in countries such as the United States where there is a large minority language, and Phakeng demonstrating policy ideas for multilingual nations such as South Africa. They both discussed how English is used as the language of instruction, but Phakeng focused more deeply than Moschkovich about how English fluency is overemphasized at the expense of mathematical knowledge and instead advocates for a more multilingual approach. She cautioned about some United States policies seem to advocate Spanish as the "other" language at the expense of non-Spanish speaking bilingual students. She also points out how, in South Africa, a change in language policy usually comes when there is a change in political power. In both situations, however, English tends to be the dominant language of assessment (Phakeng & Moschkovich, 2013). Although politically the United States does not have the same fluctuations as some nations of the Global South, it is still subject to changes in policy and language allowances in the classroom and within assessment.

When considering the language of instruction of mathematics and assessment results, studies have shown some mixed and conflicting outcomes. In a study conducted by Llabre and Cuevas of 408 late primary bilingual Hispanic students in Dade County, Florida who were given a standardized mathematical achievement test in English and Spanish, those who tested in English scored statistically significantly better than those who tested in Spanish (1983). This result was statistically significant at a 0.01 level across high, medium, and low levels of reading

comprehension in both the categories of assessment of concepts and applications. However, these students also had learned the material in English and thus were only experiencing the native tongue switch when the assessment came (Llabre & Cuevas, 1983). Another point of consideration is, as in cases where students are emergent bilingual and take assessment in English, that English becomes the language of authority and a colonial classroom effect takes place. Students are not empowered in knowledge in their own language, and the mathematics being assessed ends up becoming something for students to passively receive from a figure of power, rather than something of which they are an active part (Setati, 2005). Again, this paves the way for a more behaviorist approach to mathematics teaching and learning.

The use of a translator, if allowed in the particular assessment, has also been shown to have some success, especially in the case of complex word problems (Abedi, 2006). Abedi further noted that as students focus on real world examples and their implications, the increasing levels of linguistic complexity can be problematic for the reader who may indeed know the mathematics but not the words or even the culturally specific scenarios being used in the problem (2006). In one study in South Africa, significant improvement in task completion involving fraction interpretation, time, and bar graph interpretation was seen with native isiXhosa speakers when a translator was present and, furthermore, and greater mathematical success was seen when students were interviewed and allowed to verbally give answers instead of only being allowed to provide a written response (Sibanda, 2017). The interview gives the teacher a greater insight as to not just what solution a student obtains, but how the arrival to that answer happened. As educators, to understand the entire student thinking process is essential (Erlwanger, 1973). With the presence of a person in the classroom who can serve to interpret

vocabulary for the student, this helps to add a layer of access not otherwise present (Atabekova, Stepanova, Udina, Gorbatenko, & Shoustikova, 2017; Sibanda 2017).

Yet another example of successful assessment technique which used elements of group discussion took place in a study by Turner, Dominguez, Maldonado, & Empson (2013). This American study presented word problems dealing with fractions in both English and Spanish. Students were encouraged to think about the word problems and discuss in small groups in the language of their choice and, when they came to talk to the class as a whole, students were allowed to continue with their language of choice. The teacher code switched regularly to bring students into the discussion who were both native English and native Spanish speakers. It was noted that this was one of the first times that many of the students who were emergent bilingual were positioned to have the power to express strong levels of mathematical thinking and ideas, and this made an impact on the way in which they interacted with mathematics outside of the afterschool setting (Turner, Dominguez, Maldonado, & Empson, 2013). Though this particular method has its own challenges, including the need for a teacher who can flow easily between languages, for more bilingual scenarios such as those sometimes faced in the United States, this can be a highly effective strategy. Additionally, one must consider the policy of the area. In Malaysia, though the country has large pockets of Chinese population, a 2003 government mandate declared English to be the official language of instruction for mathematics nationwide. With this sudden change, teachers found that they were spending more time translating than teaching mathematics content (Lim & Presmeg, 2010). This highlights some of the limitations of bilingual education and instead suggests the need for a less siloed approach to create an

understanding of mathematics that uses a more blended approach with regards to language of instruction.

Translingual Education in Mathematics

The argument has been made more recently to make a switch from the concept of bilingual education to translingual education. With translingual education, instead of isolating one particular language and then another, students and teachers both may freely switch between languages and often without translation. Signage in classrooms may appear in multiple languages as may lessons themselves (Garcia & Wei, 2014). One could argue, even, that the aforementioned Turner, Dominguez, Maldonado, and Empson (2013) after-school program study already borders on translingual instead of bilingual. In terms of translingual elements that would occur in an active classroom, researchers have identified four principles: *con respecto* (with respect), *con cariño* (with fondness), *como familia* (like a family), and *con acompañamiento* (truly together) (Garcia, Ibarra Johnson, & Seltzer, 2017).

In mathematics education, these four translingual principles were recently applied to a study in a second-grade classroom where the students and teacher both used a multilingual approach to communicate mathematical ideas. When students provided ideas on a subtraction problem, one in English, and one in Spanish, the teacher switched between languages, did not offer any translation, and focused on the symbolic nature to ensure all students were part of the learning process. The authors cited the fact that students were brought into the conversation as equals regardless of language of choice was key to the principle of *con respecto.* The teacher in the classroom used common constructivism classroom techniques, such as small group discussion, eliciting strategies, and having students do the majority of the sense making. The fact that the teacher built on student ideas that were presented with incorrect results but used them as

a launching platform for discussion was cited as an example of *con cariño,* and the eliciting of small group discussion among students as well as whole class discussion accompanied the principles of *como familia* and *con acompañamiento* (Maldonado, Krause, & Adams, 2018).

What was key to the Maldonado, Krause, and Adams (2018) study as well as the one presented by Turner, Dominguez, Maldonado, and Empson (2013) was the ability to overcome that natural switch to behaviorism from constructivism that has been seen as problematic in the bilingual and multilingual mathematics classrooms. This concept of culturally responsive language practices are not necessarily unique to English and Spanish in the United States. For example, ubuntu pedagogy, focusing on inclusiveness and equity in the classroom, has been a leading educational driver in Namibia’s multilingual classrooms for over a decade (Biraimah, 2016). However, the particular focus on translingual approaches in mathematics education and using these to comprehend the additional language of mathematics is a groundbreaking shift.

With any educational shift, though, techniques must be looked at with caution when considering extrapolating the results to all combinations of languages in classrooms around the world. As an example, a study of an attempt to create a multilingual-style environment for students learning mathematics in a two-way immersion program in English and Korean, where the language of mathematical instruction was predominantly Korean, saw difficulty in elements of curriculum sequencing and pedagogy that flowed differently in Korean culture and language than in the English-language, American cultural situation. It was difficult to mesh these together to create a true flow and meaningful mathematical discourse (Lee & Lee, 2017).

Challenges for Teachers

Yet another challenge in both effective bilingual and multilingual education is when the teacher does not share the same language and culture of the students. In terms of strategies that

have been shown to aid students who are emergent bilingual in this scenario, one particular study in a fifth grade classroom in the United States found student success in the learning of geometry concepts when the teacher used visual aids. Although some physical tools were used such as concrete manipulatives, protractors, and measuring devices, the majority of the findings were focused on the use of gestures and movement so that students were able to create a visual to accompany the mathematical vocabulary being used by the teacher (Shein, 2012). Similarly, in a study of an after-school program geared toward bilingual youth in English and Spanish, the importance of gesture, revoicing, and diagramming in a dual language way whenever possible was found to be highly effective (Turner, Dominguez, Empson, & Maldonado, 2013). Indeed, multiple studies have shown that when gestures have been used in mathematics, both students whose native tongue is the language of instruction and those for whom it is not have been shown to make gains (e.g., Church, Ayman-Nolley, & Mahootian, 2004; Ng, 2016). Therefore, one could argue that gesturing is not simply a technique to promote learning among students who are emergent bilingual but rather it is simply an effective practice in mathematics education regardless of language (Church, Ayman-Nolley, & Mahootian, 2004).

Regarding teachers of mathematics, especially at the secondary level, frustrations exist in how to balance content delivery with strategies to aid the students who are learning a country's language. In Sweden, where the teaching approach to mathematics tends to be of a nature where students are largely independently responsible for their learning, teachers made adjustments as immigration led to more multilingual classrooms. It was found that a more guided approach correlated positively with student success in mathematics, but without entirely moving away from student-driven learning (Hansson, 2012).

In the United States, a survey of current and pre-service urban STEM teachers whose classrooms were primarily composed of emergent bilingual students was conducted. The survey participants expressed uncertainty on knowledge of strategies they could use, and some favored leaving the language portion of instruction to a designated ESOL teacher. However, the teachers also reported feeling conflicted about the role of an ESOL teacher who did not understand the STEM content being taught. The participants were then given a semester-long program to help integrate language strategies into their everyday teaching in order to help their students who were emergent bilingual, and the teachers did report feeling more comfortable with their emergent bilingual populations upon the study's completion (DelliCarpini & Alonso, 2014). However, the professional development provided essentially instructed the teachers on how to help students with language strategies rather than fundamentally change the look and feel of the classroom itself, as the previously mentioned studies did. Here, English was still used as the sole language of instruction and instead of incorporating strategies from the students' own language and culture, students were encouraged to come into the English language classroom in the more traditional way. What remains to be seen is, as the emergent translingual techniques in mathematics education have been mostly incorporated into the primary classroom setting, if this same type of model may be used in the secondary setting effectively, as the intervention to be undertaken in this study will examine.

Peer Mentoring and Tutoring in the Multilingual Setting

In the case of emergent bilingual students who have experienced educational interruptions, the "buddy system" is one of the key recommendations from the best practices compendium that multiple states cite when working with emergent bilingual students with interruptions in formal education (SIFE's) (Spaulding, Carolino, & Amen, 2004). Beyond having

a paired companion, though, for situations where there are high-performing students who demonstrate fluency in more than one language, research has shown success in peer mentoring and tutoring, especially in mathematics and science classrooms.

The Mathematics and Science Partnership in New York City, for example, developed the Peer Enabled Restructured Classroom (PERC) program, where bilingual teaching assistants worked in an intensive five-week summer program with urban high school students who had demonstrated struggles in mathematics and science as determined by state test results. The primary language of 93% of the currently struggling students was Spanish, with the remaining 7% being primary speakers of Korean or Bengali. Qualitatively, the students reported a deeper connection with the teaching assistants due to commonalities in language and home experiences. Quantitatively, the students in the study experienced test score gains post-intervention (Gerena & Keiler, 2012). Similar findings have been seen in primary grade studies, where emergent bilingual students have found support in peer tutoring from higher grade students within their same school. In a study with a cross-age peer tutoring model with eight sessions centered around the reading and interpretation of texts from various aspects of STEM, discipline-specific vocabulary gains were noted in mathematics, science, and technology (Peercy, Martin-Beltrán, Silverman, & Nunn, 2015).

In situations where the teacher does not share the common native tongue with the students, an outside connection is encouraged in order for the strategies for emergent bilingual students in mathematics to be fully realized (Demski, 2009). Through positive bilingual peer interactions that are discipline specific, gains have been seen in cases like those mentioned above

independently of the language of the teacher. For topics that are heavy in vocabulary, language is even more critical.

The Role of Language in Probability Research

Within mathematics, probability is a topic that is crucial in the development of quantitative literacy and should use a multitude of examples from a wide range of fields in order to be taught effectively (NCTM, 2018). Furthermore, when compared to more algebraic-based mathematics, probability holds the unique quality that the interpretation of specific events in an ever-changing context is crucial to its understanding (e.g., Davis & Hersh, 1981; Polya, 1954; Wilder, 1972). Due to this unbreakable intertwining between language and calculation, the attainment of probabilistic knowledge holds a challenge for both the learner and the teacher and, when the learner has a different native language, the complications are even more pronounced. Often in probability, this is due to the lexical ambiguity of the English language in the mathematics classroom. In 1991, Durkin and Shire identified the following four types of lexical ambiguities:

- Homonymy: where two words share the same form but have two different meanings (Example: mean of a sample versus acting in a mean way)
- Polysemy: where a single word can have multiple meanings but the meanings are related to each other

  (Example: The word sample is both a noun, meaning the data collected, or it can be a verb and indicate the act of data collection, as seen in sampling techniques.)
- Homophony: two or more words have different spellings and meanings but are pronounced the same

(Example: sum versus some; symbolic homophony also appears frequently in statistics where the upper-case Greek letter sigma (Σ) indicates a summation while lower case sigma (σ) indicates standard deviation of a population)

- Shifts of application: where words can have different meanings from different perspectives

  (Example: Random can be used to describe a sample and an assignment process, among other things.)

As can be seen in the given examples of lexical ambiguity, all four have the potential to be present in standard probability problems. Kaplan, Fisher, and Rogness (2009) delved deeper in to the lexical ambiguities unique to statistics generally and developed a list of thirty-six suspected lexically ambiguous terms. Though they were only able to test five due to the scope of their study – association, average, confidence, random, and spread – the three most commonly found in probability problems of these five (association, average, and random) all were determined to be linked to expression of confusion in problem understanding by students participating in their study (Kaplan, Fisher, & Rogness, 2009). As lexical ambiguities have been shown to be associated with decreased rates of word acquisition, communication problems, and decreased comprehension and learner motivation (e.g., Kidd & Holler, 2009; Petten, 2006), it is imperative that these be addressed in the mathematics classroom as well.

The other aspect of language within probability that has been supported as being problematic is the use of sentence modifiers such as “at least,” “at most,” and “given that.” For second language learners, modifiers are usually one of the last parts of speech conquered, as is recommended practice in instruction (Stringer, 2013). Thus, if a student is emergent bilingual,

depending on their stage of language acquisition, they may not have yet conquered the part of speech that is key to knowing operations associated with probability calculations. Indeed, this has been noted for students whose native languages are as diverse as Chichewa, the primary language of Malawi (Kazima, 2006) and Spanish (Lesser & Winsor, 2009). Thus, a unique barrier can be seen in the attainment of probability knowledge as the combination of lexical ambiguity and consistent use of modifiers comes as a double-tap to the learner.

Furthermore, the assessment of probability knowledge has been of a particular challenge. Teachers who come from a background of mostly teaching algebra may lean toward a focus on calculations and assessment forms of a more traditional nature when beginning to teach concepts in probability and statistics and need professional development to think outside of the proverbial box (Visnovska & Cobb, 2019). Statistical content naturally lends itself to be assessed with an even more widespread use of authentic tasks, case studies, portfolios, and critiques (Garfield & Chance, 2000).

The goals and challenges of probability and statistics education must not be viewed as independent from the goals and mission of mathematics education in general, however. Though the trend to a separation into those focused on mathematics education and statistics education has been noted in recent years, the interplay between topics and knowledge on the boundary is crucial for reasoning in both facets of the mathematics education whole (Groth, 2015). The seminal 2007 *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report* made particular note that, reaching back to NCTM's 1989 *Curriculum and Evaluation Standards for School Mathematics*, that Data Analysis and Probability was one of the five content strands, and the interest in statistics has increased among educators and, in assessment, there has been a

rapid increase in the presence of data analysis and probability questions on the National Assessment of Educational Progress (NAEP) examinations.

When considering the purpose and goals of statistics education, Gal and Garfield (1997) in their book *The Assessment Challenge in Statistics Education* articulated the following eight-item list which outlines the major goals for students:

Goal 1: Understand the purpose and logic of statistical investigations.

Goal 2: Understand the process of statistical investigations.

Goal 3: Master procedural skills.

Goal 4: Understand mathematical relationships.

Goal 5: Understand probability and chance.

Goal 6: Develop interpretive skills and statistical literacy.

Goal 7: Develop the ability to communicate statistically.

Goal 8: Develop useful statistical dispositions. (pp. 3 – 5)

The GAISE Report echoed these sentiments then in 2007, with the goals of Data Analysis and Probability for the pre-K-12 level listed as follows:

- *Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them;*
- *Select and use appropriate statistical methods to analyze data;*
- *Develop and evaluate inferences and predictions that are based on data; and*
- *Understand and apply basic concepts of probability* (p. 5)

While the goals stated by Garfield and Gal and then in the GAISE Report are fairly broad-based in nature, they have found their way into the Common Core State Standards Initiative (CCSSI) in

a very explicit way beginning in the Grade 6 curriculum and stretching across high school. Although Puerto Rico falls under the United States educational system, the territory did not elect to adopt the Common Core. Rather, the Puerto Rico Core Standards (PRCS) are used. Tables 1 – 5 highlight the standards which will be focused upon in this study. In the tables, if a directly comparable PRCS standard exists, it is written below the CCSS in italics in Spanish, the language of publication of the PRCS mathematics standards document, to provide cross-alignment between the standard documents.

Table 1

CCSS.MATH.CONTENT.7: Use random sampling to draw inferences about a population

Standard	Description
7.SPA.1	Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences. *No direct equivalent in the Puerto Rico Core Standards.*
	(CCSSI, 2010; PRCS, 2014)

Table 2

CCSS.MATH.CONTENT.7: Investigate chance processes and develop, use, and evaluate probability models

Standard	Description
7.SPC.5	Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around ½ indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.
6.E.16.2	*Reconce y aplica la probabilidad de que el evento ocurra. (Los números mayores indicant una mayor probabilidad de que el evento ocura. Una probabilidad cerca de 0 indica pocas probabilidades de ocurrencia; una probabilidad de ½ indica un evento cuya ocurrencia tiene las mismas probabilidades de ocurrir o no ocurrir; y una posibilidad cercana a 1 indica una probabilidad de que ocurra el evento).*

(CCSSI, 2010; PRCS, 2014)

Table 3

CCSS.MATH.CONTENT.HSS: Understand independence and conditional probability and use them to interpret data

Standard	Description
HSS.CP.A.1	Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").
8.E.11.1	*Describe el evento como subconjuntos de un espacio muestral (el conjunto de resultados) al usar las caractericas (o categorias) de los resultados o como unions, intersecciones o complementos de otros eventos (“o,” “y,” “no” diagrama de Venn).*
HSS.CP.A.2	Understand that two events *A* and *B* are independent if the probability of *A* and *B* occurring together is the product of their probabilities, and use this characterization to determine if they are independent. *No direct equivalent in the Puerto Rico Core Standards.*
HSS.CP.A.3	Understand the conditional probability of *A* given *B* as $P(A \text{ and } B)/P(B)$, and interpret independence of *A* and *B* as saying that the conditional probability of *A* given *B* is the same as the probability of *A*, and the conditional probability of *B* given *A* is the same as the probability of *B*. *No direct equivalent in the Puerto Rico Core Standards.*

Standard	Description
HSS.CP.A.4	Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities.
(+) ES.E.46.1	*Construye e interpreta tablas de frecuencias de dos entradas cuando se relacio nan dos categorias y se clasifica cada objecto. Usa la table de dos tenradas como espacio muestral para decider si los sucesos son independientes y para aproximar las probabilidades condicionales (ejemplo: Reunir datos mediante un muestreo aleatorio de los estudiantes de la escuela sobre su materia preferida entre Matemáticas, Ciencias e Inglés. Estimar la probabilidad de que un estudiante escogido al azar prefiera las Ciencias, dado que dicho estudiante está en décimo grado. Hacer lo mismo con otras materias y comprar los resultados).*
HSS.CP.A.5	Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations.
(+) ES.E.46.2	*Reconoce y explica los conceptos de probabilidad condicional e indepencia en el lengugaje y situaciones de la vida diaria (ejemplo: Comparar la probabilidad de sufrir de cancer de pulmón si se es furnador, con la probabilidad de ser furnador si se sufre de cáncer de pulmón).*

(CCSSI, 2010; PRCS, 2014)

Table 4

CCSS.MATH.CONTENT.HSS: Use the rules of probability to compute probabilities of compound events

Standard	Description
HSS.CP.A.6	Find the conditional probability of *A* given *B* as the fraction of *B*'s outcomes that also belong to *A*, and interpret the answer in terms of the model.
ES.E.47.1	*Halla la probabilidad condicional de A dado B como la fraccíon de resultados de B que también perenecen a A, e interpreta la respuesta en términos del modelo.*
HSS.CP.A.7	Apply the Addition Rule, *P(A or B) = P(A) + P(B) - P(A and B)*, and interpret the answer in terms of the model.
ES.E.47.2	*Aplica la regla de la suma, P(A o B) = P(A) + P(B) – P(A y B) e interpreta la respueta en términos del model.*
HSS.CP.A.8	(+) Apply the general Multiplication Rule in a uniform probability model, *P(A and B) = P(A)P(B|A) = P(B)P(A|B)*, and interpret the answer in terms of the model.
ES.E.47.3	*Aplica la regala general de la multiplicacíon en unmodel de probabilidad uniforme, P(A y B) = P(A)P(B|A) = P(B)P(A|B) e interpreta la respuesta en términos del modelo.*

(CCSSI, 2010; PRCS, 2014)

Table 5

CCSS.MATH.CONTENT.HSS: Calculate expected values and use them to solve problems

Standard	Description
HSS.MD.B.7	(+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game). *No direct equivalent in the Puerto Rico Core Standards.*

(CCSSI, 2010; PRCS, 2014)

Using the CCSSM standards, one can see clear trends aligned with what Gal and Garfield articulated as essential toward statistical thinking, data analysis, and heavy focus on probability, especially in the high school standards. Tables 2 – 5 specifically show focuses on probabilities, from simple to compound, with a particular focus on independence and conditional probability

calculations. In line with this, NCTM in *Catalyzing Change in High School Mathematics* echoed the two "Essential Concepts in Probability" to be independence and conditional probability understanding (2018, p. 66), as influenced back to the works of Moore (1990). These concepts form a backbone for later student understanding of expected value and, later in the high school statistical standards, prediction from linear models. Without probability skills, it is impossible to achieve full mastery of tasks such as linear model interpretation due to a lack of understanding of prediction, or to understand displays of data without knowing the likelihood of occurrence. Therefore, it can be seen that probability is essential in the understanding of statistics and getting students to the point of making solid statistical inferences. For this reason, the study described in the next chapter will aim to have at its forefront the goal of increasing student understanding of probability, with statistical reasoning as a secondary focus. The statistical standards outlined in the CCSM were used to design the Probability in the AfterMath instrument, to be described later in the research design and methodology section, along with common difficulties in student understanding, which are discussed in the next section, that make these goals more cumbersome to achieve.

Statistical Thinking

During the last two decades, progress has been made in identifying students' thinking in probability and statistics at the middle school level, where the first domain label appears in the CCSSM. Mooney (2002) developed and published a framework to identify the progress that middle school students make through statistical thinking, known as the Middle School Student Statistical Thinking (MS3T) framework. He named the four stages in this early secondary level statistical thinking as follows:

- *Describing Data*

- *Organizing and Reducing Data*
- *Representing Data*
- *Analyzing and Interpreting Data*

Through describing data, students are reading charts, graphs, and tables to determine key elements, graphical comparisons, and interpretation of individual values. In organizing and reducing data, students begin to elicit knowledge regarding measures of center and variation in ways that move far beyond the mean, median, and range. In representing data, students move to the next phase in which they can create their own graphs, tables, and charts to display data and identify what key elements should be displayed to tell the statistical story. Finally, in the stage of analyzing and interpreting data, students can begin to ask questions about effects of specific data values, comparisons, and data manipulation (Mooney, 2002). Even though Mooney's framework was intended for middle school students, as can be seen through the aforementioned progression of probability and statistics content through the high school CCSSM, this same general form of thinking and progression of sophistication for knowledge applies to the upper secondary grades as well.

Though statistics are used across the scientific fields, from the social sciences to the hard sciences, where one piece sharp criticism has come, especially when considering empirical research, is in practices of interpretation and appropriateness of significance tests resulting from basic probability knowledge, or lack thereof (Batanero, 2000). In fact, a domino effect has been seen among students without a strong grasp of conditional probability knowledge then having issues with the concept of what can and cannot be said regarding significance in hypothesis testing. In his seminal article *Controversies Around the Role of Statistical Tests in Experimental*

Research, Batanero (2000) notes the worries of multiple statistics education researchers about the importance of hypothesis testing knowledge, especially in biomedical studies, and that conclusions which are set to potentially affect the health of thousands are based on a faulty knowledge of significance and Type I and Type II error at an alarming rate. While statistical and probabilistic knowledge has worked its way into the CCSSM and the Mathematics Florida Standards (Florida Department of Education, 2014), its importance across the fields cannot be overstated.

Understanding of Sample Space

In terms of the reasoning behind students' struggles with probabilistic reasoning, many researchers have pointed to misunderstandings in sample space to be a starting point as, without understanding what a probability is being found *of*, the ability to comprehend and execute more complex calculations becomes moot (e.g., Abrahamson, 2009; Gillies, 2000). How this misunderstanding is handled, though, is crucial, with certain studies showing teachers defaulting to a *telling* approach as opposed to an approach rooted in student discovery, possibly due to limited content knowledge themselves (Chernoff & Zazkis, 2011). In fact, when asked questions to elicit knowledge about appropriate sampling techniques, pre-service teachers demonstrated lack of knowledge about various sampling methods and the importance of randomization (de Vetten, Schoonenboom, Keijzer, & van Oers, 2018). That being said, learners have responded better to the concept of sample space with more constructivist approaches where they have the opportunity to form a sample space as an initial activity in understanding (Chernoff & Zazkis, 2011). Interestingly enough, one particular study of fourth and fifth grade students showed no difference in performance between those working with small sample sizes versus those with

large ones, but both groups showed tremendous growth in general probabilistic thinking (Polaki, 2002).

Support for the necessity of the knowledge of sample space has gone further as to be seen in ideal learning approaches for the mastery of conditional probabilities. As an illustrative example, a study of university students instructed in conditional probability calculations and interpretation in a medically-based context found that those who were taught using frequency formatting from tree diagrams fared better than those who were instructed using traditional Bayesian formula methodology (Chow & Van Haneghan, 2016). Though certain studies have found a mix between methods produces the most optimal student learning (e.g., Even & Kvatinsky, 2010), the inclusion of a time where students are able to build on the sense-making found within sample space understanding is still crucial.

NCTM has supported the use of visuals and the importance of data organization in aiding the understanding of sample space, promoting the use of contingency tables as a method by which to understand relationships between sample spaces in probability calculations, particularly in conditional probabilities. They cite this as crucial for students to visualize not only the sample space at hand, but the independence or dependence of various events within that sample space (NCTM, 2018). This emphasis is rooted in the seminal work of Moore (1990), who surmised that the teaching of combinatorics does not advance a conceptual understanding of probability in students the way that a focus on independence, conditional probabilities, and the multiplication rule do. The GAISE Report also supports this method and points out that, when combined with raw data collection, a contingency table can be used to attain a first level of statistical knowledge in terms of probability, and then this serves as a platform to then look for patterns within the data

by means of linear regression analysis (Franklin et al., 2007), which then ties in directly to the CCSSM standards found in Tables 3 and 4.

Manipulatives and Spreadsheets in Statistics Education

The aforementioned sense-making for sample spaces can come in the form of activities involving concrete manipulatives such as dice, cards, and coins. However, as educational technology continues to advance and take an ever-increasing prominence in the classroom setting, the role of technology as an aid in solidifying probabilistic thinking cannot be ignored. Within the GAISE Report, there is a notable call for the use of technology in conjunction with the calculation and understanding of probabilities. For calculations involving probabilities from the normal curve, the authors went so far as to suggest that methods using technology were preferable to the more traditional table of values methods that are often still used in algebra classrooms (Franklin et al., 2007).

For those classrooms with readily available internet access and connectivity for students, web-based applications based on Java programming such as those available through random.org and stapplet.com have begun to see use in recent years for digital replacements to concrete manipulatives.

Indeed, as technological develops, Greer (2000) made the pointed declaration, "the ratio

$$\frac{\text{access to data}}{\text{analystical and critical tools for interpretation}}$$

is accelerating out of control" (p. 7). The use of spreadsheets for large data management, whether through traditional office software packages such as Microsoft Excel or statistics education focused products such as Minitab, have been deemed especially helpful for the ability not just to record and perform calculations on large data sets but in their ability to provide quick visual

representations that can then be analyzed and interpreted. This allows for students to more readily use their time on data interpretation rather than the mechanics of calculations (Ben-Zvi, 2000).

The Importance of Context

With probability and statistics, the integration of relevant contexts is crucial in order to achieve quantitative literacy (NCTM, 2018). The importance of context is seen even when students are describing statistical terminology themselves. As an example, in a study of interviews conducted longitudinally with Australian primary school students to determine their conceptions of average, the language which the students chose to use in describing averages were nearly unilaterally involving context natural to their own existence and would not have been chosen by those outside of the Australian primary school world (Watson & Moritz, 2000). Taking it a step further, however, the true practice of statistical knowledge has been seen to develop when can use skills learned theoretically in practice within one's own field. In one study focused on vocational students, a boundary-crossing approach was taken to show students the types of statistical analysis they would be performing and reading on output from various machines as they related to chemistry principles. The students were able to see such items as variance and *p*-values used in-context to help determine allowable boundaries for various machines, and it was reported that students were witnessed to break out of the binary knowledge dissemination of school versus work (Bakker & Akkerman, 2014). While students in this study were not secondary but vocational and collegiate, it is important to remember that, when considering students in the secondary setting, this population will have a multitude of post-secondary destinies. Workplace culture is just as identifiable among learners as ethnic and linguistic aspects of cultural identity.

Culturally Responsive Curriculum

When school curriculum is overseen by any nation's government, there is the risk factor for the dominant culture to diminish the importance and existence of minority cultures (e.g., Dachyshyn & Kirova, 2011; Okazaki & Teeter, 2009; United Nations, 2007). This may be seen in nations where colonialism is a strong part of the history, but it also exists within cultures that are native to the country (Dachyshyn & Kirova, 2011). Researchers have noted a striking need for more culturally responsive curriculum due to issues of social justice, especially within the mathematics classroom (e.g., D'Ambrosio & D'Ambrosio, 2014; Leonard, Brooks, Barnes-Johnson, & Berry, 2010; Suad Nasir, 2002; Suad Nasir & Cobb, 2002). Whatever the origin of these discrepancies, it is educationally of the utmost importance for students to be able to identify themselves within curriculum and culture and for a natural respect to grow about that self-identification (Dachyshyn & Kirova, 2011).

Neocolonialism, Cultural Imposition, and Underrepresentation

Neocolonialism refers to the propagation of socioeconomic and political influences that reinforce various aspects of former colonial rulers, including factors of culture (Afisi, 2019). A key example of cultural imposition can be seen in the case of social work education for students who will eventually serve areas highly populated by those of a different background than themselves. For example, at a predominantly white institution (PWI) in the United States which was located in proximity to Tribal Colleges, it was found that the establishment of a partnership between the institutions offered an authentic means by which to learn instructional strategies and engage in cultural sharing that could prove beneficial in the field. This is referred to as "nation building," and this case of it was marked by the inclusion of tribal elders in the decision-making processes as well as having representative faculty from the American Indian community

alongside faculty from the white majority. This partnership is set to continue and be closely monitored to see if it may serve as a model for other similar situations in the United States (Heitkamp, Vermillion, Flanagan, & Nedegaard, 2015).

Looking for oneself in curriculum is not only a delicate matter of ethnic culture but sexual culture as well. When considering LGBTQ youth enrollment in STEM education in general, although as an all-encompassing group a slight decrease in enrollment is seen (though not yet statistically significantly so), males are engaging in advanced math and science education courses in rates that are lower than previously recorded (Hughes, 2018; Gottfried, Estrada, & Sublett, 2015). Indeed, while LGBTQ females are 18% more like to stay in STEM than heterosexual women, males who are LGBTQ are 17% less likely to persist than heterosexual males (Hughes, 2018). This has led for a call to action for more to promote the works of LGBTQ individuals within the curriculum and even an international LGBTQ STEM day (Gottfried, Estrada, & Sublett, 2015; Bandelli, 2018). Although this view on inclusiveness of those of various sexual orientations as an issue culture in curriculum is still developing, it is rapidly garnering attention in Global North countries.

Gaudelli and Wylie discuss an interesting case in Thailand, where at the Marjoon School in Bangkok, Buddhist principles serve as the guiding force at the school. However, the school does not consider itself religious – rather, it aims to have the ideas of respect which are key to the practice. While the school does have a centralized curriculum that is presented to the Ministry of Education for approval, they are not taking curriculum from the Ministry itself, which is common practice. Although learning core subjects is still present, there is also a strong push to learn about learning, why learning is important, and a push for self-reflection on feelings and

emotions, as is key in the Buddhist culture. It was noted that, as the school goes higher in grade level, that this reflective nature comes out perhaps most strongly within science courses, where the teachers feel that the students' grasp on principles scientific inquiry is much stronger than would be the case with a purely national curriculum, which is based more on testing and rote memorization. In fact, the school has served as a teacher preparation ground as well and links to a university. Additionally, it welcomes expatriate teachers who are looking for a more spiritual approach to general education (Gaudelli & Wylie, 2016). Although this is certainly a different approach for putting oneself into their education, this case is interesting as it transcends identification of a marginalized group but rather allows an opportunity for anyone from any cultural group to view education a bit differently.

Whatever the methodology, the issue of identifying within a classroom situation is imperative as, without buy-in, the education can feel imposed instead of encouraging. Through positive peer relations and an inviting learning environment, however, true engagement can be seen (Higinio Dominguez, López Leiva, & Licón Khisty, 2014). These various looks at a purposeful sense of self will hopefully pave the way for the multifaceted approaches that must be taken for a truly culturally responsive curriculum.

Cultural Responsiveness: Sustainability in Curriculum

When a cultural experience includes a natural disaster, this lends itself to the incorporation of environmental issues across the curriculum. As an illustrative example, there has been an ongoing practice at Ithaca College in New York regarding the incorporation of sustainability ideas within calculus material (Rogers, Pfaff, Hamilton, & Arken, 2015). Through the Multidisciplinary Sustainable Education Project, modules have been shared and made publicly available for student and faculty use. Although the majority of the projects in the

courses offered do consist of environmentally focused topics, such as “Mauna Loa Yearly Average CO_2” and “Country Photovoltaic Energy Production”, the other two pieces of sustainable development mentioned by Gaudelli and Lan, society and economy, are further considered by encouraging students to mathematically model the economic impact of such items as seen in the “Gini Coefficient Transition to Integration” module (Rogers, Pfaff, Hamilton, & Arken, 2015). The idea of making these modules and projects so well-packaged is intriguing, if advertised and disseminated properly to a point where their existence and best practices of use are known. Furthermore, to reach students at the lower levels, there was an initial scaling of projects for the algebra-based classroom. Here the focus lies on authentic and live data collection to then begin curriculum integration while still aligning to mathematical standards (Hamilton & Pfaff, 2013).

This concept of including environmental topics across the curriculum as an inclusion of cultural response is not a new one when looking at the global community, however. Beginning in 1997, South Africa established the Environmental Education Curriculum Initiative (EECI) to insure the incorporation of environmental topics into courses and also to further a push for outcomes-based education (OBE). While there has been heavy national debate regarding what is being called the “institutionalization of environmental education,” the educational system of the country has been working since inception to find a harmony between a qualitative feeling of students having increased environmental awareness and hard, measurable quantitative results of this fact. One key concern in terms of the push for environmental education to be managed within schools is that indeed the schooling should be a cause for students to rise and push for reforms to environmental policy that will provide for a more sustainable future. However, as the

schools themselves are generally government run, the same people making the policies are the ones testing student knowledge. Therefore, there is an outcry and concern regarding the checks and balances of environmental education within the country (le Grange & Reddy, 1997).

Though sustainability education certainly reaches beyond environmental education, as nations come in to the discussion at different levels, the environmental side has been a natural place to begin. Whether the integration be at the collegiate or preK-12 level, the goals do remain the same: to ensure that students of all ages are becoming citizens with a greater level of awareness of their place within the planet and what may be done to promote a stronger future.

Ethnomathematics and Cultural Responsiveness in Mathematics

Within Western mathematics, there has been a trend, especially at the secondary level, for teachers to adopt a classroom model that is seen as hierarchical with the teacher in the lead and the students as the receivers of knowledge. This model, though, has been found to perpetuate feelings of oppression within the classroom setting (Hand, 2012; Lubienski, 2002). However, when students are allowed to interact and use their own language and colloquialisms in sense-making, a shift in authority and more positive self-efficacy has been noted, both in traditional in-school settings as well as informal after-school contexts and in communities (e.g., Cobb & Hodge, 2002; Erath, Prediger, Quasthoof, & Heller, 2018; Langer-Osuna, 2018; Suad Nasir & de Royston, 2013). Indeed, Gay (2013) has made the repetitive case for the need for culturally responsive teaching to fuel students' efficacy and empowerment in a way that "connects in-school learning to out-of-school living." In recent years, the conversation within mathematics has changed, and there has been a noticeable movement for greater degrees of critique and understanding in mathematics education in terms of social justice, especially with the growing use of Critical Race Theory (CRT) within mathematics education literature (Guitérrez, 2013).

It has further been recommended that, in research rooted in cultural responsiveness, that it is important for student voices to be heard and not just that of the researcher as an authority. Ladson-Billings (1995) advocates the use of quotes from research participants, especially in situations where the researcher is in the role of the "other." Through this, not only can classrooms become more responsive, but educational research about them as well.

As a forerunner and then almost parallel to the ideas of changing the face of Western mathematics has been the importance of the inclusion of non-Western mathematical principles into curriculum. The ideas of ethnomathematics and looking to cultural mathematics present in indigenous and underrepresented communities took hold in the 1980's and 1990's with notable works by Marcia and Robert Ascher, Ubiratan D'Ambrosio, Arthur Powell and Marilyn Frankenstein, and Norma Presmeg, to name a few (Ascher & Ascher, 1986; D'Ambrosio, 1990; Powell & Frankenstein, 1997; Presmeg, 1998). In more recent years, the face of ethnomathematics has changed to also articulate elements of identity and power (e.g., Knijnik, 2012). This change comes in response to concerns about ethnomathematics having inherent issues of trying to Westernize that which is not Western and using culture in a way that can come off as disingenuous and thus lead to unintentional, yet still harmful, othering (Pais, 2011). Through the melding of ethnomathematics and purposeful identity-mindedness, researchers are now exploring culturally responsive mathematics curriculum that not only uses themes present in a students' identities and experiences but also creating an environment to give those learners ownership over their quests for mathematical understanding.

When students are able to see themselves in mathematics in a meaningful way, the results have been striking. As an illustrative example involving a marginalized group in the United

States who are indeed citizens but have a distinct culture, a study with ethnomathematics undertones was conducted in 2012 with more than 700 elementary school students in southern Alaska. In this particular study, tasks were developed with approval and suggestion from Yup'ik Eskimo elders in order to assist in representing, measuring, grouping, and place value. The two tasks, entitled *Picking Berries* and *Going to Egg Island*, integrated Yup'ik ways of measuring alongside western mathematics and used common Yup'ik ideas of estimation in gathering of eggs and picking of berries. Students in both urban and rural schools alike were found to have significant gains in measurement and place value performance when compared to control groups who did not use the Yup'ik-infused curriculum (Kisker et al., 2012).

Though this is just one of many studies of the inclusion of cultural themes in mathematics curriculum, the importance of this example is the case of the students' dual identities as both American and Alaskan Indigenous. This border identity situation leads to uniqueness when standards of education are held by the dominant nation but students may identify with an almost nested nation within a nation. This can be seen further in the case of Puerto Rico.

Mathematics Education in Puerto Rico

The island of Puerto Rico has seen a long history of colonization, with the first official European colony being founded in 1508 by Juan Ponce de León. Having changed hands to colonization by the United States in the Spanish-American War, the United States has maintained the island as a territory since 1898, and the Foraker Act of 1900 established an educational system governed by the United States as its colonizer (Venator-Santiago, 2019). Although Puerto Rico maintains status as a United States outlying territory and is bound by United States educational requirements, the mathematical testing performance results of Puerto Rican students are often scored separately from the mainland United States and, unfortunately,

with consistently lower performance. When considering the 2015 scores on the Programme for International Student Assessment (PISA), the United States reported an average score of 15-year-olds in mathematics literacy of 470, while Puerto Rico had an average of 378. This difference was significant at the $p < .05$ level. Additionally, sixty-two countries outranked Puerto Rico for 15-year-old students in mathematics literacy, including the mainland United States. The mathematics results for Puerto Rico only outranked those of three countries – Kosovo, Algeria, and the Dominican Republic (NCES, 2019).

Although the PISA assessment itself is produced in English and French, the test, booklets, and all supporting materials are translated from English or French into the language that is considered primary in the country or territory in which the test is being conducted. In the case of Puerto Rico, the PISA is translated and administered in Spanish. Then, a team of Puerto Rican educators was then tasked with instrument review to affirm that the Spanish and colloquialisms used in the assessment were aligned with the typical Spanish used in Puerto Rico (Ying Chan et al., 2014). Thus, this measure does aim to test student mathematical literacy in their language of instruction, siloed from any translation on the part of the student.

When considering the poverty factors that plague Puerto Rico, the tale of mathematical underperformance becomes even more stark. For schools in the United States with 75% or higher Free and Reduced Lunch, the average mathematics literacy PISA 2015 score was 427, significantly below the 470 average. In Puerto Rico, the score for that same group was 361 (NCES, 2019). As 91.9% of students attending school in Puerto Rico are Free and Reduced Lunch eligible, second only to the District of Columbia (Ed.gov, 2019), it becomes clear that poverty is highly correlated with the mathematical performance.

In 2016, Bozick, Malciodi, and Miller (2016) published an important study of 1,189 immigrant ninth grade students in American classrooms from 112 countries and Puerto Rico. In this, they found a strong correlation between the PISA and Trends in International Mathematics and Science Study (TIMSS) country scores of the student's country of origin and their performance on post-migration math assessments. Although this trend has been shown internationally with immigrants and their new home country and thus is not unique to the United States (Giannelli & Rapallini, 2016), what stands out with this study is its ability to show the bigger picture of the challenges of the Puerto Rico immigrant student. Every year spent in the United States leading up to the ninth grade showed improvement for the students in the Bozick, Malciodi, and Miller study, with the strongest changes being in the students coming from countries with the lowest PISA and TIMSS scores. With the students from Puerto Rico, they fell into the unique category of having some of the least exposure to mainland United States schools, having low PISA and TIMSS scores, and being a top immigrant-sending territory (Bozick, Malciodi, & Miller, 2016). This goes to further show that the special population of students from Puerto Rico who have made the most recent immigration surge post-Hurricane Maria face a variety of unique challenges in terms of their mathematics education.

Theoretical Framework

In order to properly analyze the unique situation that students who are most affected by natural disasters find themselves, the theoretical framework of intersectionality theory is used in this study. In early feminist theory, there was a growing cry to have the very specific voices of those employing feminist theory from different racial perspectives heard. The exclusion of feminists from races outside of Caucasians was historically noted as early as in the 19th and 20th centuries, and activists who were non-Caucasian sought out a theory that helped to bring in their

true perspectives (Hancock, 2016). This was seen strongly in the issues brought forward of race and class seen in Black feminism (Cooper, 2016). Thus, intersectionality theory was born.

First developed by Crenshaw (1989), intersectionality theory has roots in feminism to discuss how different oppressors may intersect to form a power structure that can work against a particular individual or group of individuals. Though there has been some criticism toward intersectionality theory for its fluidity and open-ended nature, it has been seen by many researchers as a success story in feminist theory because of its recognition of the ability of many micro-oppressors to influence a sense of identity and experience (Davis, 2008). No matter the intersection, the goal of intersectionality inherently remains the same – to serve as "a systematic approach to understanding human life and behavior that is rooted in the experiences and struggles of a marginalized people" (Dill & Zambrana, 2009, pp. 4). Furthermore, intersectionality theory allows for a focus of factors that can influence a person or group of people as an oppressor in the moment, versus a historical oppressor. As an example, if one is facing a disease, such as dementia, this would be an oppressor in someone's life for a specific length of time and thus helps to describe a shifting sense of identity (Hulko, 2009). For those affected by natural disasters, this is yet another example of a sudden oppressor and, while a part of an experience for some immigrants, certainly one that does not hold for a lifetime.

Intersectionality theory has grown in its popularity in research involving immigrant populations, as it is able to describe the impact of multiple aspects of the experience of those coming into a new country beyond issues of race and class. Although these issues are often included as factors in the immigrant experience, intersectionality offers a chance to look at other impactful elements, such as having job skills that may not meet the demands of a new area

(Kaushik & Walsh, 2018) or health disparities (e.g., Havkivsky et al., 2014; Viruell-Fuentes, Miranda, & Abdulrahim, 2012). Among research into the Latino/@/x community of immigrants, Latina/o Critical Race (LatCrit) Theory has risen as an extension of Critical Race Theory, and this in itself is a hybrid of intersections to show aspects of immigration and language faced by this community (Pérez Huber, 2010). When looking further into the way intersectionality theory has been used to describe the Latino/@/x immigrant educational experience in the United States, the issue of educational policies as oppressors bring in yet another layer, especially in the consideration of policies that are distinctively opposed to immigration, bilingual education, and affirmative action, with these policies being seen as an additional hurdle in aiding students of this demographic in college preparedness (Núñez, 2014).

For immigrants, marginalization is a common theme, but for those immigrants who find themselves in this position due to involuntary means, the marginalization can become even more pronounced. Here, the analysis of the identity of those students who are attempting to attain education after an interruption caused by a natural disaster is found at the intersection of poverty, language, and neocolonialism. Thus, the *AfterMath Intersectionality Framework* was developed for this study, as seen in Figure 2 on the following page:

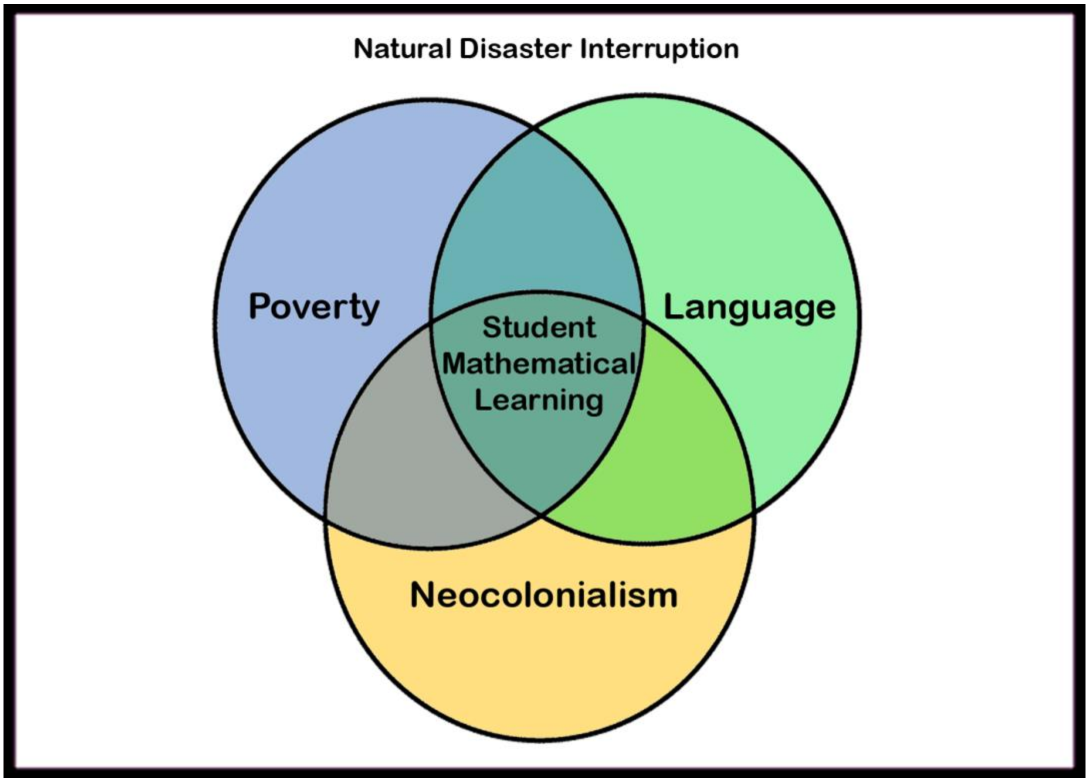


Figure 2: AfterMath Intersectionality Framework

These particular issues are seen as the most influential due to the profound impact they have on the educational attainment of the students who have had interruptions, particularly in mathematics. The poverty effects that are often felt strongest by those most effected by natural disaster also correlate to mathematical performance (Spencer, Polachek, & Strobl, 2016). Students with language issues, as previously discussed, often struggle with word problems due to the general vocabulary as well as the mathematical vocabulary needed to make strides (Turner, Dominguez, Maldonado, & Empson, 2013). Finally, the natural disaster phenomenon, particularly hurricanes and cyclones, disproportionally affect small island nations and territories, most of whom were colonized by a nation from the Global North and were forced into an educational system that accordingly matched their ruler (Spencer, Polachek, & Strobl, 2016). Therefore, schooling itself can be seen as an oppressor as it came in a dictatorial way. All of this

combines to form a sense of identity that can lead to students not identifying positively with mathematics education or even formal education and schooling. This can become even more pronounced after an educational interruption.

For those who want to continue their education but who find themselves at the intersection of these distinctive events with the looming overhead of the interruption due to the natural disaster, the next question to come is, “Now what?” In order to achieve success within mathematics, all these factors of the *AfterMath Intersectionality Framework* must be addressed and in a purposeful way so that students can regain power over their learning and see themselves within mathematics in a way that their culture and background is not a hindrance but rather just another aspect of their identity.

Table 6 on the following page shows the connections among the constructs of the *AfterMath Intersectionality Framework.* The literature throughout this chapter has been used to support its creation, but key pieces are highlighted below to illustrate the intersections that are critical to the framework’s development. Each cited pieces of supporting literature exists already within the overarching theme of natural disaster interruption and then connects two factors in the framework. For example, Spencer, Polacheck, and Strobl specifically make the connection between neocolonialism and poverty in mathematics education (2016). The goal of the *AfterMath* study is to explore all the intersections of the framework and their effects on student mathematical learning.

Table 6

Connections between AfterMath Intersectionality framework and supporting key literature in education in natural disaster interruptions

Intersection	Supporting Key Literature
Poverty + Language	Vallas (2014)
Poverty + Neocolonialism	Spencer, Polacheck, & Strobl (2016)
Neocolonialism + Language	McCormick (2016); Willans (2017)
Student Mathematical Learning + Combinations of Poverty, Language, and Neocolonialism	Lamb, Gross, & Lewis (2013)

Although extensive literature exists in the constructs of poverty, neocolonialism, language, and student mathematical learning, these key pieces demonstrate literature that has focused on the intersection of the constructs with the lens of natural disaster interruption and its effects on education.

Summary

This chapter examines the literature surrounding mathematics education in emergencies, the challenges of emergent bilingual students in mathematics, the importance of probability and statistical learning within mathematics education, the need for culturally responsive curriculum, the situation of mathematics education currently in the United States territory of Puerto Rico, and how the theoretical framework of intersectionality can be used to bring these unique facets together to shape a critical lens through which to conduct an intervention to aid the students who have entered Florida's mathematics classrooms due to the impact of Hurricane Maria. Through the guidance of this literature, an intensive and culturally responsive intervention has been designed to bring students in a small group setting with strong peer support, as was shown in the

literature to be a promising solution. The next chapter will outline the specific research design and methodology to be used in this study and show how a translingual, culturally responsive approach may help with the learning of probability concepts.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

Introduction

Within this chapter, the research question is first restated and the mixed method design of the study discussed. The study population, setting, and sampling methods are described as well as the data collection and procedures. The intervention is described in detail as well as the process for selecting the final tasks. The data sources are described, and the protocol for interviews and post-task reflections are discussed. Data analysis procedures for both the qualitative and quantitative data are shared.

Research Question

The following research question was developed in order to specifically investigate probability and statistical understanding and knowledge attainment after an interruption in formal education due to a natural disaster. The research question was posed as follows:

- *How does a culturally responsive, mentor-guided mathematical intervention support the understanding of topics in probability for students with educational interruptions caused by natural disasters?*

Research Design

The purpose of this study was to determine how students' understanding of probability changes over time after undergoing an intensive intervention that is both culturally responsive to their status as natural disaster refugees and translingual in nature. A mixed methods study design was used which consisted of qualitative interviews alongside quantitative analysis to determine benchmarks and gains made in the understanding of probability. The research conducted employed the principles, as described by Tashakkori and Teddlie (1998) as *multilevel research*. Within multilevel research, different methods – quantitative or qualitative – are used to address

levels in a system and form an overall conclusion (Creswell & Plano Clark, 2007). The Triangulation Design – Multilevel Model was chosen due to the fact that data collection of qualitative and quantitative components for this study occur concurrently with one not being used for the creation or modification of the other. This design also emphasizes an equal weighting of the quantitative and qualitative results and is marked the by use of validating quantitative results to aid in the validation of the qualitative results (Tashakkori and Teddlie, 1998). If the quantitative and qualitative results do not agree, this can pose a challenge and limitation of this model (Creswell & Plano Clark, 2007). However, in the case of the study design to be described, the Triangulation Design – Multilevel Model is able to support the research goals even if a disagreement were to arise. This would indicate that there was a contrast between the students' perception of their own understanding and the quantitative evidence of that understanding in the form of performance on the tasks and changes from the pre-test to post-test. Therefore, in order to support the research and elicit optimal simultaneous quantitative and qualitative weight in forming a cohesive conclusion, the Triangulation Design – Multilevel Model was used to analyze the data sources in the study.

Population and Sampling

In line with the goals of this study, the population for this study was comprised of students who fell into one of two categories. The first category was students who had immigrated to the mainland United States from Puerto Rico due to the circumstances surrounding Hurricane Maria. Any student who immigrated to the mainland United States and took up permanent residence prior to September 20, 2017, the date of Hurricane Maria's landfall on the island of Puerto Rico, was not be considered in this first category. If a student had previously been educated in the mainland United States but then returned to Puerto Rico for at least three

consecutive academic school years before re-entering the mainland United States after Hurricane Maria, they could be considered a part of the first population category. To be considered, students also were required to be enrolled in high school as either a freshman, sophomore, or junior within the state of Florida.

The second category was comprised of students who were enrolled in either their junior or senior year of high school in Florida, who were fluent in both English and Spanish, and identified ethnically as Latino/@/x. Additionally, the second category of students only contained those who had been educated in the mainland United States and were not designated as immigrants due to Hurricane Maria. The other defining characteristic of these students was that they all have successfully completed coursework in probability and were currently enrolled in dual enrollment or Advanced Placement (AP) coursework for mathematics.

The sample for the study consisted of students from a public high school in Central Florida who fell into one of either of the two categories. The high school chosen provided a convenience sample for the researcher, and purposive snowball sampling was used in order to obtain the specific student participants in the study. Potential students were identified with assistance from the administration of the high school as well as the teachers of the mathematics department. As the school district in which the student participants were enrolled does not actively track immigration from United States territories to the mainland, assistance from the school administration and teachers were imperative in order to identify the potential qualifying participants. Students identified as potential participants were individually informed about the study verbally which included information of its time requirements, goals, with emphasis being placed on the voluntary participation aspect. Prior to the beginning of data collection, approval

was obtained from the Institutional Review Boards (IRB's) of both the university and the public school district. The approval letters from both IRB's are included in Appendix B. Every potential student was given a calendar of dates as well as the consent form for participation, also located in Appendix B. The consent forms explained the purpose of the study and emphasized that it was a voluntary participation program. The procedures and confidentiality of the study were additionally explained in the consent form.

The resulting cohort of student participants included fourteen high school students currently enrolled in a public high school in Central Florida that provided sample for the study. A cohort size of fourteen was chosen to align with suggested practice standards for classrooms where the instruction is in English but English is not the primary language of the learners. The American Council on the Teaching of Foreign Languages (ACTFL) suggests a class size of 10 – 12 as ideal for instructors, with students preferring 10 – 20 as a class size, according to survey. Additionally, a class size beginning at 7 is identified as "uncomfortably small," and 4 or less as "impossibly small" (ACTFL, 2010). Echoing this sentiment, the International Teaching English as a Foreign Language (TEFL) Academy sets the standard globally for partner institutions that all class sizes must be a maximum of 14 (ITEFL, 2019). Thus, it was determined that having a total of fourteen students with seven in each of the two categories would be an ideal sample to meet the small class standards while not being "uncomfortably small" in a particular designation.

Seven members of the cohort were comprised of students who had immigrated from Puerto Rico due to being displaced by Hurricane Maria since September 20, 2017 and had an interruption in their formal education due to the hurricane. These seven students were currently enrolled in mathematics coursework at the high school, in Algebra I, Algebra II, or Geometry.

Table 7 below provides the background information of this cohort, referred to as the mentee cohort. All students in the study were given pseudonyms in accordance with IRB privacy guidelines.

Table 7

Probability in the AfterMath Mentee Cohort Background Information

Name	Gender	Age	Year	Arrival to Mainland	Current math class	Language spoken at home
Carlos	Male	16	Junior	2018	Algebra II	Spanish
Gabriela	Female	14	Freshman	2019	Algebra I	Spanish
Genesis	Female	16	Junior	2017	Algebra II	Spanish
Hector	Male	15	Sophomore	2017	Geometry	Spanish
Jesus	Male	16	Junior	2018	Algebra II	Spanish
Jose	Male	16	Junior	2018	Algebra II	Spanish
Luis	Male	14	Freshman	2019	Algebra I	Spanish

The remaining seven members of the cohort served in the role of same-language and culture mathematical mentors, referred to as the mentor cohort. Those students were all self-identified as Latino/@/x and had a mix of self-identified nationalities. These mentor students were all junior and seniors and enrolled in the same high school as the mentees. All mentors were considered high-achieving mathematically and had either successfully completed or were currently enrolled in dual enrollment or advanced placement (AP) mathematics coursework. Table 8 on the following page provides the background information on the mentor cohort. As with the mentees, students in the study were given pseudonyms in accordance with IRB privacy guidelines.

Table 8

Probability in the AfterMath Mentor Cohort Background Information

Name	Gender	Age	Year	Nationality Identification	Math classification	Language(s) spoken at home
Andres	Male	17	Senior	Colombia	AP	Spanish and English
Angel	Male	16	Junior	Colombia	Dual Enrollment	Spanish and English
Eduardo	Male	17	Senior	Dominican Republic	Dual Enrollment	Spanish
Leticia	Female	18	Senior	Mexico	AP	Spanish
Mia	Female	16	Junior	Argentina	Dual Enrollment	Spanish and English
Paola	Female	16	Junior	Puerto Rico	Dual Enrollment	Spanish and English
Ricardo	Male	17	Senior	Ecuador	Dual Enrollment	Spanish

Role of the Researcher

The researcher in this study was employed at the school site of the convenience sample. Although the researcher had previously or currently served as the instructor for all seven mentor students in their statistics coursework, the researcher had not served as the instructor for any of the mentee students nor had previous associations with the cohort prior to the study. In order to ensure an environment for the study focused on research, the classroom in which the focus groups and inquiry-based tasks took place only allowed entry to members of the mentor and mentee cohorts. The researcher recorded the data and, using the *AfterMath Theoretical Framework*, performed the data coding and analysis within the constructs of the framework so as to limit personal bias.

The researcher had the background as a teacher of mathematics and statistics for twelve years at the time of the study. Her teaching background included introductory level collegiate statistics teaching in both two-year college and high school settings. Additionally, the researcher had seven years experiences within the Advanced Placement Statistics community in scoring of the free response portions of the examinations and thus brought this previous assessment experience to the task development and analysis portions of the study.

Data Sources

Student participants in the *Probability in the AfterMath* intervention took part in activities that included a pre-intervention focus group interview, a content knowledge pre-test (for the mentees only), five inquiry-based tasks, a post-intervention focus group interview, and a content knowledge post-test (for the mentees only). The following section describes each of the data sources in detail.

Pre-Intervention Focus Group Interviews

Both pre-intervention and post-intervention focus group interviews were conducted during 30-minute time slots in a roundtable setting. The mentors and mentees were interviewed separately, but both the same protocol guided both sets of interviews, as outlined in Figure 3 on the follow page:

Probability in the AfterMath Interview Protocol
1. What has been your overall experience in learning mathematics? 2. What has been your biggest challenge in learning mathematics? 3. When you hear the terms “probability” and “statistics,” what comes to your mind? 4. Do you think of statistics differently than other mathematics? 5. How do you think being Latino/@/x influences your learning in mathematics? In probability and statistics? 6. What do you wish was different about your experience in learning probability and statistics?

Figure 3: AfterMath Interview Protocol

Those being interviewed were encouraged to engage in open discourse, with the questions serving as guidelines for the general discussion. Student responses were recorded, and the recordings were retained in encrypted digital storage and later transcribed by the researcher. Written notes were simultaneously taken by the researcher. Student responses to the interviews were coded using the *AfterMath Intersectionality Framework.* The qualitative analysis procedures for the interviews are described later in this chapter in the *Qualitative Analysis* section.

Content Knowledge Pre-Test

In the next session that mentees met following the pre-intervention focus group interview, the mentees took part in a probability content knowledge pre-test to establish a baseline. The test contained seven free response questions covering simple probabilities, compound probabilities involving the addition rule, multiplication rule, and conditional probabilities, and probability questions involving dependence. The test itself was modified to match the type and style of question found in *A New Approach to Learning Probability in the*

First Statistics Course by Keeler and Steinhorst (2001), which also served as a base model for the development of the inquiry-based tasks. Reliability analysis was conducted on the test to determine validity using Statistical Package for the Social Sciences (SPSS) software, and the results of the reliability analysis are discussed in the Results chapter. The mentee students were given 30 minutes to complete the pre-test, and this was later used in comparison to the post-test. The pre-test is located in Appendix B.

Inquiry-Based Tasks

Task Development

In order to design the task portion of the intervention, named in this study as *Probability in the AfterMath*, tasks were modified from the seminal study *A New Approach to Learning Probability in the First Statistics Course* by Keeler and Steinhorst (2001). The tasks were modified to be culturally relevant in terms of topic matter pertaining to the natural disaster experience, immigration and migration, and being presented in both English and Spanish.

For the task modifications, faculty members from the university in which the study originated, who are experts in the field, were consulted to help determine the appropriateness of the tasks for the students who would receive the intervention. The tasks were additionally aligned to the Common Core State Standards in probability and statistics, as previously described in the literature review. Then, two English-Spanish bilingual mathematics educators were consulted to assist with task translations as well as to insure readability by aiding in the identification of terminology and statistical wording that is potentially problematic for a typical emergent bilingual student. One educator was an El Salvador native and works as an educator in Florida at upper primary level. The other educator was a Puerto Rico native and teaches AP

Statistics in New England. These two educators were chosen for their knowledge but also the different accents and wording they bring from different regions ensured that no translations were too localized. Once the translation and task creation were completed, a pilot trial of the tasks was scheduled. The piloted tasks were completed by a cohort of students of mixed ethnic backgrounds and language skills who were additionally asked to give feedback and help determine the average time for task completion. From there, modifications were made based on the results of the pilot tests, and five final tasks were chosen to be the focus of the intervention.

Task Descriptions

The tasks were designed to address the Common Core State Standards in probability that had been highlighted as most critical in *Catalyzing Change* (NCTM, 2018). The approaches to the understanding of sample spaces by having students be involved in their own data creation was emphasized by the research of Chernoff and Zazkis (2011), and the use of independence as a basis for understanding of compound probabilities is a best practices suggested in the seminal work of Moore (1990). The tasks themselves used culturally responsive topics for the students to connect with the data and were produced in English with Spanish translations available. A description of the tasks as they align with the Common Core State Standards is shown in Table 9 on the following page and the full tasks are included in Appendix C.

Table 9

Probability in the AfterMath Task Descriptions

Task	CCSS	General Description
Home Away from Home	7.SPA.1 7.SPC.5 HSS.CP.A.2 HSS.CP.A.5	In this activity, students will begin by marking a map of Puerto Rico to identify the location from which they immigrated. This will be used as a launching point for conversations and calculations regarding independence and the basic construction of probabilities and sample spaces.
Missing the Mofongo	7.SPC.5 HSS.CP.A.4	Mentors will name locations of known Latin cuisine in the area that is the most authentic, and mentees and mentors both will offer their current location within the county. A contingency table will be formed as students identify different eateries they have tried depending on their location. Simple probability calculations will be discussed.
Missing the Mofongo *and* the Arroz con Gandules	HSS.CP.A.1 HSS.CP.A.4 HSS.CP.A.7 HSS.CP.A.8	The contingency table from last session will be revisited to now discuss the principles of restaurant visitation in terms of the addition rule and multiplication rules in-context.
Mi Familia	HSS.CP.A.3 HSS.CP.A.5 HSS.CP.A.6	Students have not migrated to this area alone – they have been joined by family and, in many cases, arrived to Florida to locations where they already have family. Looking at household demographics and reasoning for moving to this location in Florida, number of people in household given certain characteristics will be discussed and compared to U.S. Census Bureau data. Mitigating factors for household size will be investigated as a launching point for the learning of conditional probabilities.
Mi Familia in the Future	HSS.CP.A.3 HSS.CP.A.5 HSS.CP.A.6 HSS.MD.B.7	In this final task, students will use the information they have learned from the U.S. Census Bureau combined with the previously calculated probabilities to make predictions about changes in household size in the area.

Each question completed within the individual tasks was be ultimately scored on a scale modified from the scoring used internationally for AP Statistics as *E*, *P*, or *I*, where *E* designates that an answer is “essentially correct,” *P* an answer that is “partially correct,” and finally *I* for an “incorrect” answer. These scales equivocated to numerical values of 1, 0.5, and 0 for *E*, *P*, and *I*, respectively. This particular scoring mechanism allowed for the ability for students to make small transcription errors but still receive some credit for demonstration of content knowledge, while having been validated within statistics education for over two decades. A detailed rubric was used for each task in order to ensure consistent and reliable grading and categorization across all participants. The rubric for each of the five tasks are located in Appendix C. The rubrics created by the researcher for each task were validated separately by three mathematics educators, each with a minimum of seven years teaching statistics at the high school level. Suggestions for improvements, including clarification on acceptable student responses for the score of *P* on calculation tasks, provisions for equivalent forms of solutions, and allowing students to not continue to lose credit through a task if an error was made in a dependent portion, were all taken into account. Then, the rubric was finalized for each task.

Post-Task Reflections

In addition to the focus group interview conducted in the pre-intervention and post-intervention sessions, the mentee students were given, at the end of each task, a post-task reflection protocol. The goal of the protocol, seen in Figure 4 on the following page was to provide the students with an opportunity to reflect upon their own understanding and sense-making from the inquiry-based task activity.

Probability in the AfterMath Post-Task Reflection Protocol
1. What, if anything, do you feel you understand better after today's task? 2. What do you still feel unsure about related to today's task or have questions about? 3. How would you explain what we did during our session today to a friend who is in Puerto Rico?

Figure 4: AfterMath Post-Task Reflection Protocol

The goal of the post-task reflection was to give students a written opportunity to express their learning after the intervention each session. While it is recognized that many of the mentee students were verbally expressive between each other and their mentors, this was to ensure that everyone's voice was able to be heard beyond the numbers on the page. The students' responses to the post-task reflection protocol were used in the qualitative data analysis as part of their expression of understanding and interpretation of the intervention process.

Field Notes and Observations

During the twelve 30-minute sessions in which the inquiry-based tasks were being worked upon by the mentees and mentors, the researcher took field notes of observations of the interactions, conversations, and musings of the participants. These were used in conjunction with the focus group interview responses and post-task protocol responses in the qualitative analysis of the intervention.

Post-Intervention Focus Group Interview

At the end of the intervention, the mentees and mentors were again divided into two separate groups for final 30-minute focus group interviews. The same interview protocol described in the Pre-Intervention Focus Group Interview section was used to launch the conversation, but students were also encouraged to give their overall impressions and feedback on the entire intervention process. As was the case with the previous interviews, the researcher

wrote while audio recording, the recordings were stored in encrypted files, and transcriptions of the interview sessions were used for coding. The *AfterMath Intersectionality Theoretical Framework* again served as the basis for the coding categories, and the qualitative analysis section of the results goes into the detail of the student responses.

Content Knowledge Post-Test

The mentee students were given a content knowledge post-test and allowed 30 minutes to complete seven questions focused on the probability topics that had been covered throughout the inquiry-based tasks in the intervention. As was the case with the pre-test, the students were asked to complete the test individually and were given a pencil, calculator, and scratch paper. The researcher was the only person to see the tests and results. The pre- and post-test document is located in Appendix C.

Data Collection and Procedures

Data collection took place in a classroom at a public high school in Central Florida during fall 2019. After an initial mentor training meeting, the participants in the intervention met three times per week for six weeks (18 meetings) during thirty-minute time blocks. Of those 18 intervention meetings, 14 consisted of pre-intervention testing, teamwork on tasks in probability, and post-intervention testing. The remaining four sessions were set aside for pre-intervention and post-intervention focus group interviews of the mentees and mentors. The justification for the length of time and number of meetings of the project was based upon mirroring the length of time typically dedicated to a probability unit within a mathematics course, as identified by Keeler and Steinhorst (2001).

The data collection timeline and summary of events are in Table 10 on the following page:

Table 10

Outline of Probability in the AfterMath Schedule

Topic	Date(s)	Session
Mentor Training	August 16	Mentor Protocol
Mentor Interviews	August 19	Pre-Program Interview
Mentee Interviews	August 20	Pre-Program Interview
Mentee Pre-Test	August 22	Pre-Test
Independence	August 26, 27, & 29	Task 1: Home Away from Home
Simple Probabilities and Contingency Tables	September 6, 7, & 9	Task 2: Missing the Mofongo
Complements, Addition Rule, and Multiplication Rule	September 10, 12, & 13	Task 3: Missing the Mofongo *and* the Arroz con Gandules
Conditional Probabilities	September 16 & 17	Tasks 4: Mi Familia
Predictions	September 19	Task 5: Mi Familia in the Future
Mentee Post-Test	September 23	Post-Test
Mentee Interviews	September 25	Post-Program Interview
Mentor Interviews	September 26	Post-Program Interview

During the first session, only the mentors met. The researcher reviewed with them the mentor protocol, found in Appendix C. The goal of the mentor protocol was for the mentors to understand their role as a side-by-side guide with their designated mentee, know that they were

not expected to have perfect knowledge and that they may ask questions about anything of which they were unsure. Mentors were also encouraged to use whatever language best suited communication between themselves and their mentees and to flow between English and Spanish as desired. The mentors were also made aware of the time requirements, meeting dates, and purpose of the intervention.

During the next two sessions, students who constituted the mentee group and students who constituted the mentor group were interviewed separately in a focus group format to elicit conversations about their attitudes and beliefs toward probability and statistics as well as mathematics education in general. The interview protocol is in the Data Sources section of this chapter as well as in Appendix C. The focus group interviews took place during thirty-minute sessions in the same classroom that served as the site for the intervention tasks, and the students were seated in a roundtable style. For both focus group interview sessions, the conversations were audio recorded, and the recordings saved in a secure and encrypted file format. Written notes were simultaneously taken, and post-interview, the audio recordings were transcribed. The interviews were later coded to determine common themes among the mentee and mentor responses as well as the aggregation of their responses. The coding categories were aligned to the *AfterMath Theoretical Framework*, and will be described in the Qualitative Analysis section.

During the fourth session, only the mentees met in order to take a written pre-test to assess their probability knowledge. The students completed questions related to probability that were of a similar nature in terms of content to what was to be used through the five tasks of the *Probability in the AfterMath* intervention. This pre-test was intended to allow for a baseline level of knowledge and skill to be determined. The pre-tests were only be administered by the

researcher and only seen by her, as well as the results. The students were asked to complete the pre-test individually and were provided with a pencil, calculator, and scratch paper. The students were allowed 30 minutes to complete the pre-test.

The next twelve sessions (session 5-16) consisted of the mentee and mentors being paired one-on-one to complete the five tasks. Each session will involve whole group interaction, but a purposeful pairing of mentors and mentees will take place beginning with the fourth session and the implementation of Task 1. If a conflict arises and a mentor or mentee need to be switched, this may occur, but the goal of the study is to maintain the same pair throughout the entire intervention. This was purposeful so that the mentee not only has statistical guidance but also to foster a personal relationship with a student who shares his or her language. All work conducted during the sessions will be scanned by the researcher and kept secure per IRB with the students having the option to retain a copy of their work for future study and more practice.

The seventeenth session consisted of the mentees only who completed a post-test of probability skills. The students were asked to complete the post-test individually and were provided, as in the pre-test, with a pencil, calculator, and scratch paper. Students were allowed 30 minutes to complete the post-test.

The eighteenth session was the last time that the mentees met and, during this, a post-intervention qualitative focus group interview was conducted to reflect upon the program and any changes in belief of perceived strength in subject. The nineteenth session was the final meeting of the mentors, and this served as their post-intervention qualitative focus group interview to reflect upon not only the relationships they have built but also any change in efficacy in their own probability content knowledge. The interview protocol for the mentor and

mentee post-intervention focus groups is located in the Data Sources section of this chapter as well as in Appendix C. Both the mentor and mentee focus group interviews took place during thirty-minute sessions in the same classroom that served as the site for the intervention tasks, and the students were seated in a roundtable style. As was the case with the pre-intervention focus group interviews, these were audio-recorded, transcribed, and all data stored in a secure format.

Data Analysis

As indicated by the mixed methods research design, both quantitative and qualitative data were collected and analyzed in this study. The quantitative data came in the form of pre-test and post-test results and descriptive statistics on the individual inquiry-based tasks. The qualitative data had its source in the pre- and post-intervention focus group interviews, the post-task reflections, and the field notes and observations of the researcher. The data analysis for both the quantitative and qualitative components are described in this section.

Quantitative Data Analysis

Pre-Test and Post-Test Analysis

Quantitative data analysis occurred for both the pre-test and post-test. A two-sample *t*-test for difference of means was conducted in order to determine if there were any significant gains made overall when considering an aggregation of pre-test and post-test scores for all questions. Additionally, each of the Common Core State Standards tested were analyzed separately using their own two-sample *t*-tests for difference of means to see if the intervention was successful in increasing probability competency in certain topics and standards more than others. The aim of this analysis was to determine if the intervention was effective overall in aiding students in making gains in probability understanding but also if certain standards were better served by the intervention method and, for any that were not, to open the door for future study on what may

best serve those particular standards. Although the sample size for this study was expected to be small ($n = 7$), it was still desired to view gains and significance in hopes of laying the groundwork for future study.

Individual Task Analysis

For each of the five inquiry-based tasks, scoring was conducted on an *EPI* rubric as was the case with the pre-test and post-test. The grading rubrics are found both in the results section as well as in Appendix C. Descriptive statistics were calculated on each of the five tasks based on the student performance of the mentees.

Qualitative Data Analysis

Focus Group Interviews

All audio recorded interviews were transcribed and the transcriptions encrypted for security. The interviews were coded using the guidelines outlined by Saldaña in *The Coding Manual for Qualitative Researchers* (2015). Coding was conducted manually on the transcripts with the initial round of coding including descriptive codes and "inVivo" codes, in which direct quotes from the participants of the interview were noted. After all interviews were initially coded, categorization was made in line with the *AfterMath Theoretical Framework,* with all participant responses being put into one of the following categories: poverty, language, neo-colonialism, student mathematical learning, natural disaster interruption, and other, in the case that the response did not fit into a particular category. Within each category, two rounds of subcategorization were conducted based on student efficacy within each category. The interviews between the mentors and mentees were considered both separately and aggregated. With both groups, differences in frequency of responses in pre-intervention and post-intervention

protocols were analyzed to determine if a noticeable change occurred in terms of attitudes and self-efficacy within mathematical and statistical learning.

Post-Task Reflections

During the twelve sessions in which inquiry-based tasks took place, the mentee students additionally were given the opportunity to reflect post-task, and the protocol for these post-task reflections can be found both in the Data Sources section of this chapter as well as in Appendix C. The student responses to the post-task reflections were used as further clarification and evidence in student understanding and belief regarding the intervention as stated during the post-intervention interview. Figures of student responses with explanations are interwoven into the qualitative analysis in the Results chapter and are meant to work in combination with the quantitative analysis to paint a more complete conclusion, as is the goal of Triangulation Design – Multilevel Model method.

Researcher Field Notes and Observations

The *AfterMath Intersectionality Framework* served as a lens through which to guide the qualitative data analysis. During data collection, particular attention was paid to the way in which the students code switch and use the translations in their solving of the tasks. Factors common with poverty, such as mobility and living with extended family, were particularly noted in terms of student comments and reactions to the tasks. Furthermore, as students discussed their educational experiences in the pre-intervention and post-intervention interviews, attention was given to how students positioned themselves within the school setting as well as their experiences in transition due to their displacement. Field notes and observations were collected

by the researcher. The goal of this anecdotal data was to help to provide a broader view of the student learning as well as the interactions between the mentors and mentees as well as the whole group interaction.

Summary

Through the undertaking of the *Probability in the AfterMath* intervention, it was predicted that benefits to both the mentees and the mentors would be seen in terms of mathematical confidence and, in the case of the mentees, a distinctive sense of belonging in their new educational environment. This chapter has served as a guidance for the outline of the study in terms of the population desired, sampling to take place, and methods for insuring confidentiality. Additionally, it is hoped that the reader has an overview of how the structure of the intervention and purposefully chosen topics will serve as a method by which this marginalized group of students who have endured trauma may now find a place of power within the realm of mathematics.

CHAPTER 4: RESULTS

Introduction

The AfterMath intervention was conducted over the course of six weeks during August and September 2019. A total of seven mentors and six mentees participated in the study to its completion. The mentees took part in pre- and post-tests on probability content knowledge, and matched pairs *t*-tests were run to determine statistical significance of the differences in scores from the beginning to the end of the intervention. The pre- and post-test results also underwent a second set of matched pairs *t*-tests where the topics tested were organized by Common Core State Standard for Mathematics to determine statistical significance in changes by standard. Additionally, each task completed by the mentees was scored quantitatively on an Advanced Placement *EPI* scale and descriptive statistics analyzed, as will be seen in the Quantitative Analysis section to follow.

In the Qualitative Analysis section, focus group results are analyzed. The mentors and mentees participated in separate pre-intervention and post-intervention focus groups, where the student responses were audio-recorded. The interviews were then transcribed and coded in accordance with the themes of intersection in the students' experiences as defined by the *AfterMath Intersectionality Framework* – Language, Poverty, Neocolonialism, Student Mathematical Learning, and (in the case of the mentees) Natural Disaster Interruption. Although many student responses could have been coded to fit into more than one category, as is true to intersectionality theory, here after two rounds of coding the overarching category was determined for the case of the analysis to discuss the student interactions and experiences. Key quotations and clarifications from the researcher are offered in this section to provide insight into

the views of both the mentees and the mentors about their identities within the framework and understanding and perceptions of probability.

Quantitative Analysis

In this section, the pre-test and post-test results will be discussed using matched pairs *t*-tests for significance both as a whole and then by Common Core State Standard to determine if the intervention was more effective in certain areas of probability knowledge. Then, descriptive statistics for each of the five tasks individually are included. Finally, example student results are considered for each of the tasks to paint a clearer picture of student understanding of probability.

Before the data collection portion of the intervention began, one of the mentees who originally agreed to participate in the study, Gabriela, was relocated by the school at which the study took place to another public high school in the district in order to have the opportunity for more intensive English language support. Therefore, the sample size of the mentees $(N = 6)$ is seen as compared to that of the mentors $(N = 7)$. Gabriela's designated mentor, Angel, was retained as part of the study to assist in the case of the absence of any of the mentors and worked in a backup role as needed.

Pre-Test and Post-Test Analysis

Mentee students were given a pre-test and post-test on common probability concepts involving simple and compound probability calculations, contingency tables, and concepts of replacement within a sample space. Students were given up to thirty minutes to complete the test in both the pre-test and post-test setting and were provided with a pencil and four-function calculator to use during the assessment. The pre-test and post-test document as well as the scoring rubric are found in Appendix C. The scores were calculated using the *EPI* rubric, where

E indicates an "essentially correct" answer, P indicates a "partially correct" answer, and I indicates an "incorrect" answer. The specifications for what qualified as scoring an E, P, or I are located in the rubric in Appendix C. The maximum score for both the pre-test and the post-test was a 7.

Before the mentees were given the pre-test, a pilot group of fifteen high school statistics students were given the pre-test to make a determination of the internal reliability of the instrument. The test was scored according to the rubric, and reliability analysis was conducted to determine Cronbach's alpha for the instrument. The analysis showed that the test of probability knowledge did indeed have reliability that was on the high end of acceptable range of standard psychometric scales ($7\ items;\ \alpha = 0.778$) (McKelvie, 1994).

<u>Pre-Test Analysis</u>

When considering overall score, the mentee students performed in a way that indicated incomplete knowledge of probability understanding on the seven-item pre-test ($M = 1.75, SD = 0.80$). The mentees had variation educational backgrounds in terms of private and public schooling and previous mathematics exposure, but all held the common thread of having been affected by Hurricane Maria and had subsequent formal education interrupted in some way. Lamb, Gross, and Lewis (2013) also noted the trend of gaps in mathematical knowledge by those affected by interruption due to Hurricane Katrina in the Mississippi gulf region, regardless of their schooling backgrounds. Although the area of basic probability calculation received a high score, compound probability calculations and topics involving understanding of compound probabilities, as can be seen by the further breakdown of average score by Common Core State Standard tested in Table 11. Note that the maximum score per concept is 1. The first six

standards were tested by one question each on the assessment and the last standard, HSS.CP.A.8, was tested by the average score of two questions.

Table 11

Pre-test performance by Common Core State Standards for Mathematics

Standard	Description	*M*	*SD*
HSS.CP.A.1	Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").	0.67	0.47
HSS.CP.A.2	Understand that two events *A* and *B* are independent if the probability of *A* and *B* occurring together is the product of their probabilities, and use this characterization to determine if they are independent.	0.83	0.37
HSS.CP.A.5	Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations.	0.00	0.00
HSS.CP.A.6	Find the conditional probability of *A* given *B* as the fraction of *B*'s outcomes that also belong to *A*, and interpret the answer in terms of the model.	0.25	0.38
HSS.CP.A.7	Apply the Addition Rule, $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$, and interpret the answer in terms of the model.	0.17	0.37
HSS.CP.A.8	(+) Apply the general Multiplication Rule in a uniform probability model, $P(A \text{ and } B) = P(A)P(B\|A) = P(B)P(A\|B)$, and interpret the answer in terms of the model.	0.00	0.00

No mentee upon the initial pretest scored high when considering the rules of compound probabilities, particularly in the case of conditional probability calculations. This aligns with what was suggested by the *GAISE* Report (Franklin et al., 2007) and in NCTM's *Catalyzing Change* (2018) as one of the most problematic topics in probability for students. However, it was

encouraging to see that the students scored relatively well in the understanding of a sample space in general, which was to be the launching point for the *AfterMath* intervention.

Post-Test Analysis

The mentee students had a marked increase in average overall score in the seven-item post-test ($M = 3.58, SD = 0.79$). Table 12 on the following page breaks down the post-test performance further by Common Core State Standard. As was the case with the pre-test, the maximum score on each post-test standard was 1.

Table 12

Post-test performance by Common Core State Standards for Mathematics

Standard	Description	*M*	*SD*
HSS.CP.A.1	Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").	1.00	0.00
HSS.CP.A.2	Understand that two events *A* and *B* are independent if the probability of *A* and *B* occurring together is the product of their probabilities, and use this characterization to determine if they are independent.	1.00	0.00
HSS.CP.A.5	Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations.	0.17	0.24
HSS.CP.A.6	Find the conditional probability of *A* given *B* as the fraction of *B*'s outcomes that also belong to *A*, and interpret the answer in terms of the model.	0.50	0.00
HSS.CP.A.7	Apply the Addition Rule, $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$, and interpret the answer in terms of the model.	0.25	0.38
HSS.CP.A.8	(+) Apply the general Multiplication Rule in a uniform probability model, $P(A \text{ and } B) = P(A)P(B\|A) = P(B)P(A\|B)$, and interpret the answer in terms of the model.	0.33	0.24

All six mentees involved in the study received perfect scores in both HSS.CP.A.1, regarding the interpretation of subsets of sample spaces, and HSS.CP.A.2, on understanding the independence of probabilities. Though these were also the highest scoring standards of the pre-test, the increase in score to all students receiving an *E* was deemed a success worth noting.

When considering the compound probability standards seen in HSS.CP.A.5, HSS.CP.A.6, HSS.CP.A.7, and HSS.CP.A.8, all four also saw an increase in student score. The

highest percentage increase was seen in the average student scores for HSS.CP.A.6, regarding the calculation and interpretation of conditional probabilities, and HSS.CP.A.8, on the application and interpretation of the multiplication rule.

Pre-Test and Post-Test Comparative Analysis

A matched pairs *t*-test was conducted on the difference of means in pre-test and post-test scores for the mentee participants in order to determine any significance in change of score. Although the sample size was small ($n = 6$) for the analysis, overall gains were indeed noted. It was found that the mentee students' scores increased when comparing their individual scores from pre-intervention ($M = 1.75, SD = 0.80$) to post-intervention ($M = 3.58, SD = 0.79$) at a statistically significant level ($t(5) = 2.84, p = 0.036$).

In addition to running matched pairs *t*-tests on the results for the aggregation of all probability topics on the pre-tests and post-tests, matched pairs *t*-tests were run again based on the seven Common Core State Standards identified within these assessments in order to determine if the intervention may have been a factor in increased understanding within certain standards more than others. Indeed, the difference in score between the pre-intervention ($M = 0.00, SD = 0.00$) and post-intervention ($M = 0.33, SD = 0.24$) for HSS.CP.A.8 on the application and interpretation of the multiplication rule was large enough as to be statistically significant ($t(5) = 3.16, p = 0.025$). Table 13 on the following page summarizes the results of the *t*-tests by standard.

Table 13

Results of t-tests by Common Core State Standard for Mathematics

Standard	Description	$t(5)$	p-value
HSS.CP.A.1	Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").	1.58	0.174
HSS.CP.A.2	Understand that two events *A* and *B* are independent if the probability of *A* and *B* occurring together is the product of their probabilities, and use this characterization to determine if they are independent.	1.00	0.363
HSS.CP.A.5	Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations.	1.58	0.174
HSS.CP.A.6	Find the conditional probability of *A* given *B* as the fraction of *B*'s outcomes that also belong to *A*, and interpret the answer in terms of the model.	1.46	0.203
HSS.CP.A.7	Apply the Addition Rule, *P(A or B) = P(A) + P(B) - P(A and B)*, and interpret the answer in terms of the model.	1.46	0.203
HSS.CP.A.8	(+) Apply the general Multiplication Rule in a uniform probability model, *P(A and B) = P(A)P(B|A) = P(B)P(A|B)*, and interpret the answer in terms of the model.	3.16	0.025

Individual Task Analysis

Mentee students, alongside their mentors, worked on five total tasks over the course of four weeks during three thirty-minute lunch sessions per week. The pairings of mentors and mentees were kept constant throughout the study except in the case of mentor absence, in which case Angel served as substitute mentor. In the case of a mentee absence, the mentee met with their designated mentor during one of the other two weekdays to complete the tasks at hand. The mentee and mentor pairings are listed on the following page in Table 14.

Table 14

Mentee and mentor pairings

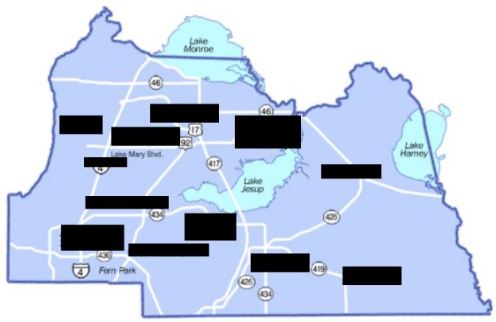
Mentee	Course	Mentor	Course	Mentor Nationality Identification
Carlos	Algebra II	Andres	AP	Colombia
Genesis	Algebra II	Paola	Dual Enrollment	Puerto Rico
Hector	Geometry	Leticia	AP	Mexico
Jesus	Algebra II	Ricardo	Dual Enrollment	Ecuador
Jose	Algebra II	Eduardo	Dual Enrollment	Dominican Republic
Luis	Algebra I	Mia	Dual Enrollment	Argentina
(Rotating)		Angel	Dual Enrollment	Colombia

The mentors and mentees sat collectively at tables when completing the tasks and, though all mentor and mentee pairings did sit together, cross-collaboration between pairings did occur occasionally during the working of the five tasks. As seen on the timeline in Chapter 3, Tasks 1, 2, and 3 each took place over three sessions, and Tasks 4 and 5 were completed in three sessions combined.

Task 1: Home Away from Home

To begin the first task, Home Away from Home, mentees began by labeling their original home location on a map of Puerto Rico. Then, they and their mentors marked their current home locations on a provided county map and proceeded with the task, as seen in Figure 5 on the following page:

The AfterMath Task 1: Home Away From Home



Where do you come from? On this map of [redacted], please have you and your mentor mark where you currently reside.

1. **Can you and your mentor mark the same location? Why or why not?**
2. **Go to others around the room and add their locations to your map.**
3. **What is your sample space now of locations?**
4. **What would be the probability of selecting someone who lives in [redacted] by chance alone? How would this change if we had not collected the locations from around the room?**

CCSS MATH Standards: 7.SPA.1, 7.SPC.5, HSS.CP.A.2, HSS.CP.A.5
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Figure 5: The AfterMath Task 1

The task was scored using the following *EPI* rubric, where a score of *E* indicates an essentially correct answer, *P* indicates a partially correct answer, and *I* indicates an incorrect answer. A score of *E* earned 1 point for the student, *P* earned 0.5 points, and a score of *I* earned 0 points. The maximum possible score on the first task was a score of 4, and the mentee responses were grade according to the rubric indicated in Figure 6 on the following page:

Question 1: **The intention of the question is to establish an early recognition of independence.**	
E	The student answered correctly that they and their mentor either can or cannot mark the same location and justified using city-name geography *or* the student correctly answered that they and their mentor cannot mark the same location as they do not live in the same household.
P	The student answered correctly regarding location but lacked or used incorrect thinking in justification of reasoning.
I	The student incorrectly answered the location marking question.
Question 2: **The intention of this direction is to create a sample space.**	
E	The student has marked on their map the locations of the other mentors and mentees.
I	The map only shows the original markings from Question 1.
Question 3: **The intention of this question is to discuss sample space in context of the collected data.**	
E	The student correctly identified the list of city locations OR the households by name of the student as their sample space.
P	The student described the sample space in non-specific terms, such as using the words "all marked cities" or "everyone's house."
I	The student incorrectly identified the sample space.
Question 4: **The intention of this question is to recognize the that probability is calculated based on representation within a sample space.**	
E	The student correctly calculated both probabilities based on each sample space scenario.
P	The student correctly calculated one of the two probabilities based on each sample space scenario.
I	The student did not correctly calculate either probability.

Figure 6: The AfterMath Task 1 Rubric

The scores for the six mentees on *AfterMath* Task 1 ($M = 3.58,\ SD = 0.45$) were indicative of a high level of understanding of the concepts of sample space in raw data collection. The boxplot in Figure 7 on the following page indicates that the data showed a strong right skew ($Median = 3.75$) .

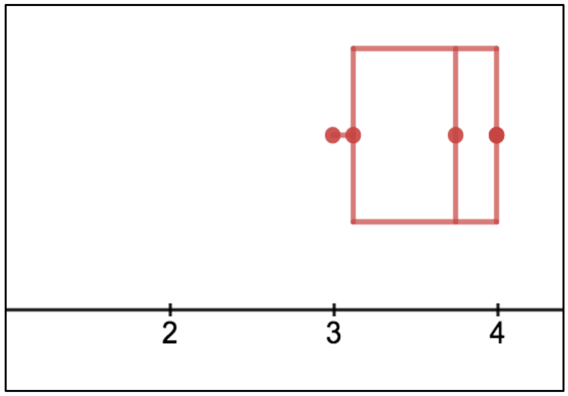
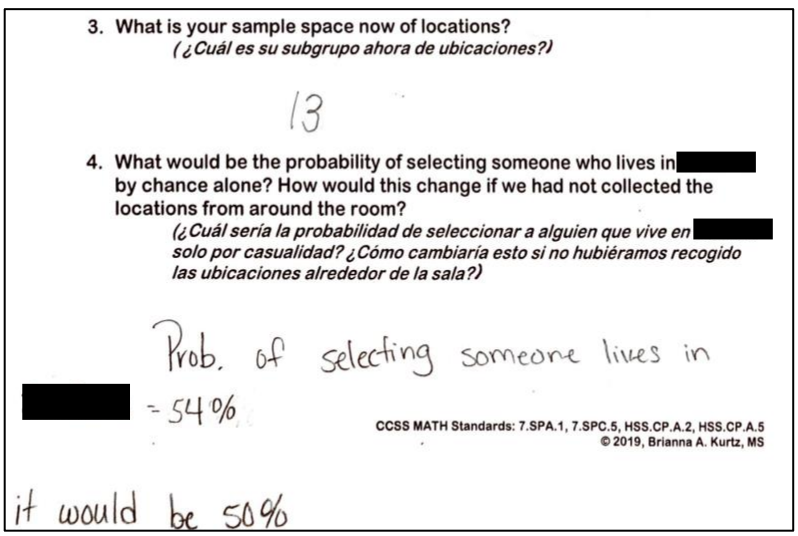


Figure 7: Boxplot of The AfterMath Task 1

Score differences were seen primarily in the creation of the sample space. One notable incorrect response was in Jesus' work. Here he listed of "13" as the sample space, indicating the sample size rather than the elements of the sample space itself, as seen in Figure 8 below:



3. **What is your sample space now of locations?**
   (¿Cuál es su subgrupo ahora de ubicaciones?)

13

4. **What would be the probability of selecting someone who lives in [redacted] by chance alone? How would this change if we had not collected the locations from around the room?**
   (¿Cuál sería la probabilidad de seleccionar a alguien que vive en [redacted] solo por casualidad? ¿Cómo cambiaría esto si no hubiéramos recogido las ubicaciones alrededor de la sala?)

Prob. of selecting someone lives in [redacted] = 54%

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it would be 50%

Figure 8: Jesus' work in Task 1

Jesus did indeed correctly respond to the fourth question and did recognize the different denominators of 13 and 2 for the two probability calculations. In the second calculation, as Jesus and his mentor Ricardo were not both from the same city stated, this resulted in the stated probability calculation of 50%.

Task 2: Missing the Mofongo

For the second task, *Missing the Mofongo*, the mentors and the mentees were given a blank contingency table with only the cities reported as current places of residence in *Home Away from Home* filled in. Then, the group as a whole began a discussion on local Latin food eateries they had tried. From the multitude of restaurants mentioned, students narrowed down the best (and most tried) to three, and they used this to fill in the contingency table as well as vote on their personal favorite. Then, two simple probability calculations were made from the contingency table results. The task before student answers were entered is seen in Figure 9 below:

The AfterMath Task 2: Missing the Mofongo

This week, we are going to use the data from the last sessions about location alongside your favorite local restaurants that, in your opinion, have the best Latin food to make a contingency table. A contingency table is a way to display data that may overlap.

			Student Location	
		[redacted]	[redacted]	[redacted]
Restaurant				

1. **What is the probability of randomly selecting a student in this study who lives in [redacted]?**

2. **What is the probability of randomly selecting a student in this study whose favorite is [redacted]?**

Figure 9: The AfterMath Task 2

The task, like *Home Away from Home*, was scored using an *EPI* rubric. A score of *E* earned 1 point for the student, *P* earned 0.5 points, and a score of *I* earned 0 points. The maximum possible score on the second task was a score of 3, and the mentee responses were grade according to the rubric indicated in Figure 10 on the following page.

<table>
<tr><td colspan="2">Contingency Table:
The intention of the question is to properly construct a contingency table from collected data.</td></tr>
<tr><td>E</td><td>The student correctly entered in values into the contingency table according to the class results.</td></tr>
<tr><td>P</td><td>The student used the correct data but mistakenly entered percentages or fractions instead of counts or the student made minor entry errors.</td></tr>
<tr><td>I</td><td>The student incorrectly entered the values into the contingency table in a way that indicated a lack of understanding of concept over transcription error. For example, a student begins to total the entries and ignores the variables vertically or horizontally.</td></tr>
<tr><td colspan="2">NOTE: If a student had a transcription error in the contingency table, this is not to be penalized in Question 1 and Question 2 unless a new error is made with these values.</td></tr>
<tr><td colspan="2">Question 1:
The intention of this question is to calculate a simple probability and recognize the organization of responses from the vertical portion of a contingency table.</td></tr>
<tr><td>E</td><td>The student has correctly found the probability and expressed the result in the form of a percentage, decimal, or fraction.</td></tr>
<tr><td>P</td><td>The student has only found the total of the column and fails to recognize that a probability is a part out of a total or has made a minor error in addition while showing the work to arrive at the response.</td></tr>
<tr><td>I</td><td>The student has made errors without showing work or fails to show an understanding of the addition of the column.</td></tr>
<tr><td colspan="2">Question 2:
The intention of this question is to calculate a simple probability and recognize the organization of responses from the horizontal portion of a contingency table.</td></tr>
<tr><td>E</td><td>The student has correctly found the probability and expressed the result in the form of a percentage, decimal, or fraction.</td></tr>
<tr><td>P</td><td>The student has only found the total of the row and fails to recognize that a probability is a part out of a total or has made a minor error in addition while showing the work to arrive at the response.</td></tr>
<tr><td>I</td><td>The student has made errors without showing work or fails to show an understanding of the addition of the row.</td></tr>
</table>

Figure 10: The AfterMath Task 2 Rubric

The scores for the six mentees on *AfterMath* Task 2 ($M = 2.75,\ SD = 0.25$) were indicative of a strong understanding of using sample data to properly construct a contingency table and then find simple probabilities from this information. The boxplot in Figure 11 on the following page indicates that the data was symmetric in nature of student performance ($Median = 2.75$).

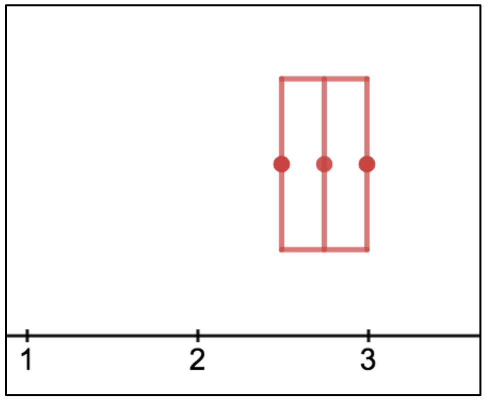

Figure 11: Boxplot of The AfterMath Task 2

Score differences were two-fold in this task. In two cases, there were minor entry errors by students in the creation of the contingency table. In another the case of Genesis, however, she correctly displayed the probability as a percent, but then combined a percent and a decimal in a manner that resulted in a non-equivalent answer, as seen below in Figure 12.

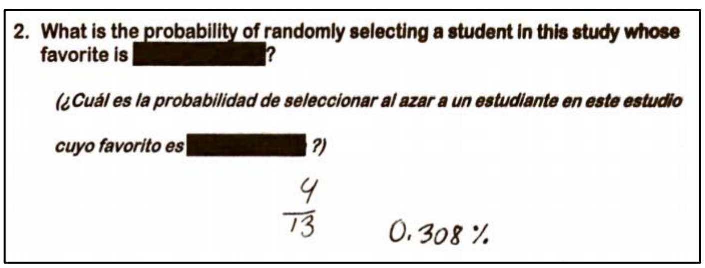

Figure 12: Genesis' work in Task 2

This is a common student mistake and often indicates a misunderstanding of the relationship between decimals, fractions, and percentages.

<u>Task 3: Missing the Mofongo and the Arroz con Gandules</u>

Task 3, *Missing the Mofongo and the Arroz con Gandules,* comes as a continuation of Task 2. Now, the mentors and mentees are presented with a filled-in contingency table based on their responses from *Missing the Mofongo.* The goal for this task is to move from the calculation of simple probabilities to that of compound probabilities, where they now are using their data

and table to find probabilities that use language such as “or,” “and,” and “given that,” as corresponds to the addition rule, multiplication rule, and conditional probability calculations. Finally, the participants selected multiple students from the contingency table to tie in concepts of independence. *Missing the Mofongo and the Arroz con Gandules* is seen in Figure 13 below:

The AfterMath Tasks 3: Missing the Mofongo *and* the Arroz con Gandules

Below is the contingency table created from our group data. On the rows are the restaurants mentioned, and in the columns are the locations where our students are from. The numbers indicate the number of students who have deemed each restaurant as their favorite based on their home location.

			Student Location	
		[redacted]	[redacted]	[redacted]
	[redacted]	2	4	1
Restaurant	[redacted]	0	2	0
	[redacted]	1	1	2

1. **What is the probability of selecting a student in this study who lives in [redacted] or whose favorite is [redacted]?**

2. **What is the probability of selecting a student in this study whose favorite is [redacted] or [redacted]?**

3. **What is the probability of selecting a student in this study whose favorite is [redacted] or lives in [redacted]?**

4. **What is the probability of selecting a student in this study from [redacted] whose favorite is [redacted]?**

5. **What is the probability of selecting a student in this study whose favorite is [redacted], who is from [redacted]?**

6. **What is the probability of selecting two students in this study from [redacted] whose favorite is [redacted]?**

7. **What is the probability of selecting two students in this study whose favorite is [redacted] who are both from [redacted]?**

CCSS MATH Standards: HSS.CP.A.1 HSS.CP.A.4 HSS.CP.A.7 HSS.CP.A.8

Figure 13: The AfterMath Task 3

As in previous tasks, an *EPI* rubric was used for scoring *Missing the Mofongo and the Arroz con Gandules*. A score of *E* earned 1 point for the student, *P* earned 0.5 points, and a score of *I* earned 0 points. The maximum possible score on the second task was a score of 7, and the mentee responses were grade according to the rubric indicated in Figure 14 below.

Question 1: **The intention of the question is to use the addition rule with one result in the column and one result in the row where an intersection occurs in the responses.**	
E	The student correctly found the compound probability using the addition rule and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly performed the numerator portion of the addition rule but eliminated the denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with the addition rule.
Question 2: **The intention of the question is to use the addition rule with independent events.**	
E	The student correctly found the compound probability using the addition rule and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly performed the numerator portion of the addition rule but eliminated the denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with the addition rule.
Question 3: **The intention of the question is to use the addition rule with one result in the row and one result in the column where an intersection occurs in the responses.**	
E	The student correctly found the compound probability using the addition rule and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly performed the numerator portion of the addition rule but eliminated the denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with the addition rule.
Question 4: **The intention of the question is to use Bayes' Theorem to calculate a conditional probability and recognizing the favorite restaurant variable as the condition.**	
E	The student correctly applied Bayes' Theorem to find the conditional probability and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly identified the numerator of the probability calculation but failed to apply the condition to the final denominator.

<table>
<tr><td>I</td><td>The student incorrectly calculated the probability by using a rule not consistent with Bayes’ Theorem.</td></tr>
<tr><td colspan="2">Question 5:
The intention of the question is to use Bayes’ Theorem to calculate a conditional probability and recognizing the student location variable as the condition.</td></tr>
<tr><td>E</td><td>The student correctly applied Bayes’ Theorem to find the conditional probability and displayed the result in the form of a percentage, decimal, or fraction.</td></tr>
<tr><td>P</td><td>The student correctly identified the numerator of the probability calculation but failed to apply the condition to the final denominator.</td></tr>
<tr><td>I</td><td>The student incorrectly calculated the probability by using a rule not consistent with Bayes’ Theorem.</td></tr>
<tr><td colspan="2">Question 6:
The intention of the question is to use the multiplication rule to find a probability when more than one subject is selected from a sample.</td></tr>
<tr><td>E</td><td>The student correctly applied the multiplication rule to find a probability with or without replacement and displayed the result in the form of a percentage, decimal, or fraction.</td></tr>
<tr><td>P</td><td>The student correctly identified only one of the two probabilities without multiplication and displayed the result in the form of a percentage, decimal, or fraction.</td></tr>
<tr><td>I</td><td>The student incorrectly calculated the probability by using non-multiplicative methods or provided an otherwise incorrect probability.</td></tr>
<tr><td colspan="2">Question 7:
The intention of the question is to use the multiplication rule to find a probability when more than one subject is selected from a sample in combination with a condition of student location.</td></tr>
<tr><td>E</td><td>The student correctly applied the multiplication rule to find a probability with or without replacement, used the student location, and displayed the result in the form of a percentage, decimal, or fraction.</td></tr>
<tr><td>P</td><td>The student correctly applied the multiplication rule to find a probability with or without replacement or correctly used the student location condition (but not both) and identified only one of the two probabilities without multiplication and displayed the result in the form of a percentage, decimal, or fraction.</td></tr>
<tr><td>I</td><td>The student incorrectly calculated the probability by using non-multiplicative methods and did not properly use the condition of student location.</td></tr>
</table>

Figure 14: The AfterMath Task 3 Rubric

The scores for the six mentees on *AfterMath* Task 3 ($M = 5.42,\ SD = 0.54$) were in line percentage-wise with previous tasks and had a similar spread, as seen in the boxplot in Figure 15 on the following page ($Median = 5.25$):

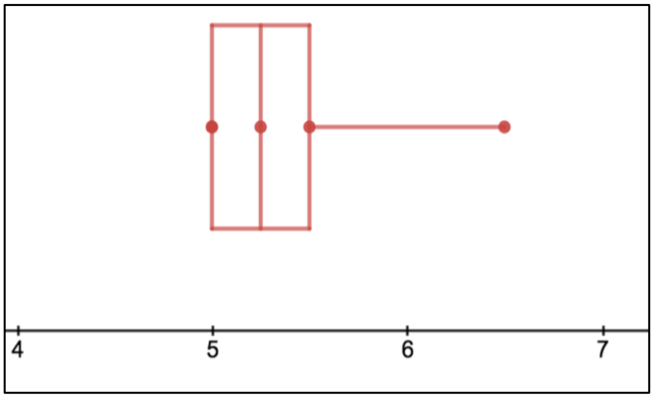

Figure 15: Boxplot of The AfterMath Task 3

Although the averages and spread among overall student scores were similar to previous tasks, a strong divide in problematic questions not previously seen was witnessed here. The students here showed a much stronger performance in the beginning three questions which used the addition rule, where all mentees scored perfectly. The disparities began in the later questions involving conditional probabilities and the multiplication rule. In fact, much of the class discussion between mentors and mentees during this task surrounded the question wording. On the final question, two students (Hector and Luis) earned perfect scores but answered the question differently. Hector interpreted the question as calling for replacement in the sample space, while Luis viewed the question as not using replacement, as seen below in Figure 16:

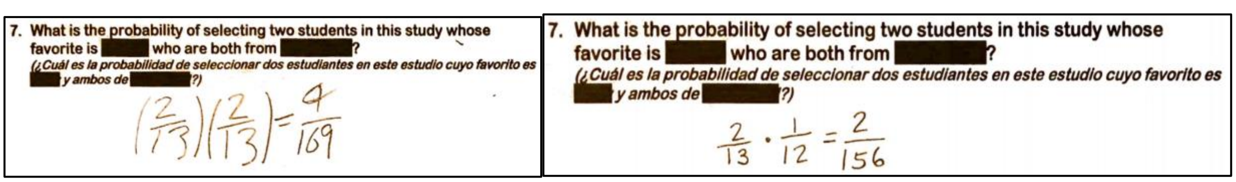

Figure 16: Student responses with and without replacement

The last two questions were left purposefully open to these interpretations to open those discussions between mentors and mentees. Both Hector's and Luis' responses above were given full credit, per the rubric.

Task 4: Mi Familia

The fourth and fifth tasks are closely linked to one another and, instead of having students gather data from each other, the mentors and mentees use data publicly available from the United States Census Bureau to analyze demographics, compare households in Puerto Rico to households in Florida, and then come to see themselves within the data. In Task 4, *Mi Familia,* students again are working toward compound probability calculations, but they are pulling data from existing tables and charts to make calculations rather than creating their own contingency table. This gives students the opportunity to know what resources are publicly available, to read existing data summaries, and make decisions as to what information is necessary to answer the question at hand. *Mi Familia* is seen in Figure 17 below:

The AfterMath Task 4: Mi Familia

Households in the United States come in many different sizes and compositions. Certain studies have shown that there can be a cultural connection with this.

Please go to www.census.gov/prod/cen2010/briefs/c2010br-14.pdf

Here we find information about United States households from the latest U.S. Census, conducted in 2010.

1. **What is the probability that a household has children, given they identify as Hispanic or Latino of any race?**
2. **What is the probability of a household having children under 18, given they live in Florida?**
3. **What is the probability of a household having children under 18, given they live in Puerto Rico?**

CCSS MATH Standards: HSS.CP.A.3 HSS.CP.A.5 HSS.CP.A.6
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Figure 17: The AfterMath Task 4

Mi Familia's EPI scale had a maximum possible score of 3, and the mentee responses were graded according to the rubric in Figure 18 on the following page:

Question 1: The intention of the question is to calculate a compound probability from a summary demographic data set and recognize which given probabilities are totals of subcategories.	
E	The student has correctly found the probability using addition and expressed the result in the form of a percentage, decimal, or fraction.
P	The student used addition to combine categories but misread at most one subcategory as a main category.
I	The student incorrectly calculated the probability by adding subcategories and main categories multiple times or through other means.
Question 2: The intention of this question is to calculate a compound probability after correctly identifying the information for the state in question.	
E	The student has correctly found the probability using addition and expressed the result in the form of a percentage, decimal, or fraction.
P	The student used addition to combine categories but misread at most one subcategory as a main category *or* used data from the incorrect state line.
I	The student incorrectly calculated the probability by adding subcategories and main categories multiple times or through other means.
Question 3: The intention of this question is to calculate a compound probability after correctly identifying the information for the territory in question.	
E	The student has correctly found the probability using addition and expressed the result in the form of a percentage, decimal, or fraction.
P	The student used addition to combine categories but misread at most one subcategory as a main category *or* used data from the incorrect state line.
I	The student incorrectly calculated the probability by adding subcategories and main categories multiple times or through other means.

Figure 18: The AfterMath Task 4 Rubric

The scores for the six mentees on *AfterMath* Task 4 ($M = 2.33,\ SD = 0.90$) were fairly consistent with the exception of one student, who scored 0.5. Although this student's answers were close to the correct results, the fact that no work was shown in the responses led to the inability to determine transcription errors in calculation. As the student's score was not determined to be an outlier, per 0.5 not falling below 1.5 times the interquartile range, it was kept in the data analysis, as seen in the boxplot in Figure 19 on the following page ($Median = 2.75$):

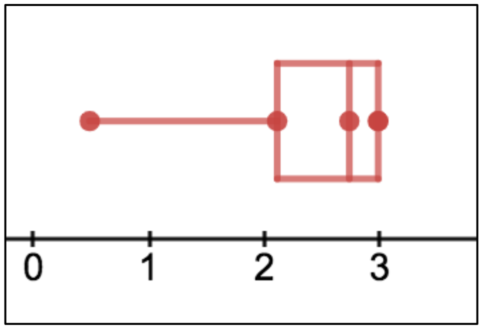
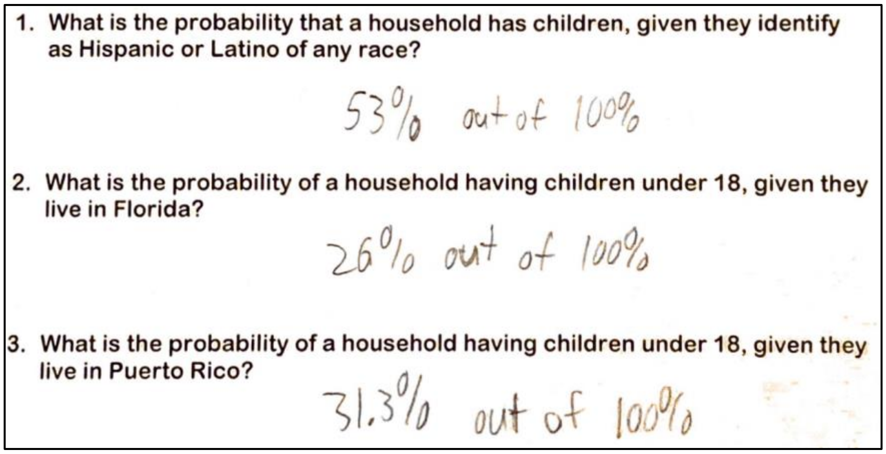


Figure 19: Boxplot of The AfterMath Task 4

Aside from the calculations, an interesting occurrence in the language realm was noted in this exercise. While in the first task much communication occurred between mentors and mentees in English and, in the second and third tasks, the language of communication was primarily Spanish, in the fourth task, the communication switched to almost entirely English again. As the earlier tasks were more culturally relevant and asked the students to reflect upon their own experiences and lives in a way that required interactive communication among the group and the later tasks used publicly available data, this was not wholly to be unexpected. In fact, one student in particular, Hector, requested to have his remaining tasks, beginning in Task 3, without the Spanish translation below so he could, “get used to how it looks in class.” This desire by Hector was interestingly in tune with the findings of Llabre and Cuevas study, who found that students performed better on mathematics assessments in their language of instruction, regardless of native tongue (1983). In Figure 20 are Hector’s responses where, not only did he arrive at the correct results, but also noted previously unseen understanding of percentages:



1. What is the probability that a household has children, given they identify as Hispanic or Latino of any race?

53% out of 100%

2. What is the probability of a household having children under 18, given they live in Florida?

26% out of 100%

3. What is the probability of a household having children under 18, given they live in Puerto Rico?

31.3% out of 100%

Figure 20: Hector's responses to Task 4

Though here Hector did not display calculations leading up to his final result, students displayed a mix of work provided, including simply listing the individual percentages that needed to be combined and then the final result, showing the addition of the individual percentages, and showing the cumulative addition of the percentages after each additional category.

Task 5: Mi Familia in the Future

The fifth and final task called for the students to identify demographic information about their own households and draw comparisons with what was found in the three Task 4 questions regarding the United States Census Bureau data. Here the students were given the opportunity for more open-ended responses and, as always, were given the opportunity to answer in English or Spanish. Though this task was based on the data not collected first-hand by the group, it was hoped that the students having the opportunity to reflect on how they and their families fit into the data would elicit the bicultural connections important to the mathematical learning of emergent bilingual students called for by Orosco (2014). The division for the *Mi Familia* set was two sessions on Task 4 and one session on Task 5. *Mi Familia in the Future* is seen in Figure 21 on the following page:

The AfterMath Task 5: Mi Familia in the Future

In Task 4: Mi Familia, you analyzed data from across the country. Now, it is time to reflect on how you and your family fit into these results now and in the future.

1. **How do you identify yourself? What characteristics make up the members of your household? How many people are in your household? Write this information below:**

2. **How do you think ethnicity and location influence household composition? Write a few sentences explaining your reasoning.**

CCSS MATH Standards: HSS.CP.A.3 HSS.CP.A.5 HSS.CP.A.6 HSS.MD.B.7
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Figure 21: The AfterMath Task 5

Mi Familia in the Future's EPI scale had a maximum possible score of 2, and the mentee responses were graded according to the rubric in Figure 22 below:

	Question 1: **The intention of the question is to recognize what constitutes a response to demographic information.**
E	The student identifies the characteristics of their household in the context of the variables from Task 4.
P	The student identifies household characteristics but does not include the inquired about demographic information that links to Task 4.
I	The student makes unrelated responses to the demographics at hand.
	Question 2: **The intention of this question is for the student to draw inferences about ethnicity and location in terms of household composition and make comparisons between themselves and the Task 4 data.**
E	The student brings in their information and the variables from Task 4 into their response.
P	The student uses variables from Task 4 to make conclusions or uses only their information.
I	The student makes superficial or irrelevant inferences for the data.

Figure 22: The AfterMath Task 5 Rubric

The scores for the six mentees on *AfterMath* Task 5 ($M = 1.25,\ SD = 0.48$) were symmetric in distribution, as can be seen in the boxplot in Figure 23 ($Median = 1.25$):

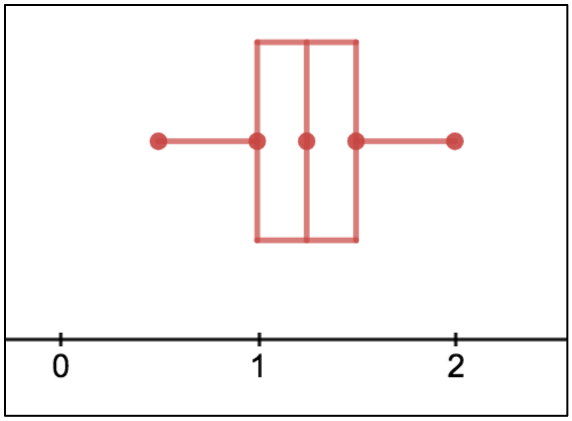


Figure 23: Boxplot of The AfterMath Task 5

The students in the first question described their identity in a variety of ways when given the open-ended question. Though the Census designation given in Task 4 was "Hispanic or Latino of any race," the students as a whole dug deeper into how they identified culturally. Table 15 below summaries the mentee's cultural identity responses within the context of Question 1:

Table 15

Summary of Mentee Identity Responses in Task 5 Question 1

Mentee	Cultural Self-Identification
Carlos	Latino
Genesis	Puerto Rican / Boricua
Hector	White-Hispanic
Jesus	Puerto Rican
Jose	Puerto Rican
Luis	Hispanic

Though by Census designation all six responses would qualify in the "Hispanic or Latino of any race" category, the mentees' identities ran deeper than the national survey categories. The complexity of the students' thinking about influences on the variables, however, came out more

in the second question. While five of the six mentees did state that ethnicity and location were indeed influences, two of the mentees (Genesis and Jose) directly discussed the effects of mobility on the reported household composition.

Qualitative Analysis

In this section, the pre-intervention and post-intervention focus groups for the mentors and mentees are discussed. The *AfterMath Intersectionality Framerwork* serves as a lens in this section for the coding of the student responses during the focus groups, and quotations are analyzed with supporting background information. In the post-intervention focus group analysis for the mentees, evidence from their participation in the intervention tasks is included to illuminate their personal reflection on their intervention experience.

Mentor Pre-Intervention Focus Group Interview

The mentor pre-intervention focus group interview took place on August 19, 2019. The interview lasted approximately thirty-six minutes in length, and all mentors were present and seated round-table style as they were asked the questions from the Probability in the AfterMath Interview Protocol (see Figure 3 in Chapter 3). Student responses were audio recorded and later transcribed by the researcher.

Using the *AfterMath Intersectionality Framework,* student responses were hand-coded as to the theme falling into the overarching theme of language, poverty, neocolonialism, student mathematical learning, or other, when the response of the student did not match a particular piece of the framework. Within the categorizations, two rounds of subcategorization occurred within each category based on student efficacy. The results of the focus group interviews by category of student response are analyzed within the framework as follows. Note that no results

from “other” are presented here, as the “other” were generally off-topic commentary or identifying information about specific teachers at the students’ current school.

Language

In discussing issues of language within their mathematical learning, the discussion between the mentors generally went along one of two paths. The first theme seen within the discussion centered around language came from the challenges of differences between the language of instruction the students are experiencing and that of their parents. The mentors reported noticeable differences between themselves and their parents when they reached out at home for aid. As an illustrative example, the following quote comes from Eduardo, a seventeen-year-old second-generation immigrant student whose parents were both born and raised in the Dominican Republic.

> I can’t get that one-on-one stuff from my parents. They’re going to be like, “I don’t know what this is. I haven’t seen this in 20-something years, and it was in Spanish. So, you not correlating with me.”

Though Eduardo was born in the northeastern United States, all schooling for him has taken place in Florida public schools. He is self-reported fluent in reading, writing, and speaking Spanish and speaks mostly Spanish at home with his family, which consists of his mother, father, and older brother.

Alongside differences in language of instruction, variations in instructional techniques were noted between the mentor students and their parents. Several shared a common frustration on differences in approach that were rooted in cultural educational differences. Ricardo is an eighteen-year-old dual enrolled senior who completed a first course in statistics at the end of his junior year. A first-generation immigrant student who was born in Ecuador, all of Ricardo’s

schooling has taken place in Florida public schools. Although Ricardo learned English and Spanish simultaneously, Spanish is the language spoken nearly exclusively in his home.

> *Ricardo:* For me and my parents, in like the multiplication and division kind of math, they would help me. But since they learned it from Ecuador, when my mom taught me division, she did some weird thing with the numbers and like lines [draws diagonal slashes in the air]…
>
> *Leticia:* Oh!
>
> *Angel:* The lines!
>
> *Ricardo:* Yeah, I didn't understand any of that. But I mostly understood, um, the American way of doing it, so after multiplication and division, when it got to um, more difficult algebra and geometry and beyond, my mom said just to use Khan Academy.

Ricardo here is describing the lattice method of multiplication and division. A mathematical technique for centuries, it has seen more popularity outside of the United States, although in recent years, it has started to be included in some elementary classrooms (Boag, 2007; Nugent, 2007). The other two students who spoke in recognition of this technique have parents who were educated in Mexico, in the case of Leticia, and Colombia, in the case of Angel. This further shows a regionalization of this approach to multiplication and division.

However, it is important to note that not all students felt that the disconnect with their parents was purely linguistic. Mia, whose mother is from Argentina, contrasted the group with the view that the reasoning for the difference in techniques and ability to help was more generational:

> It's not about that my mother is Hispanic… It's that she's older now, and she doesn't use that kind of math from her job. It's not something she remembers that she could help me with.

In addition to linguistic and culturally-based differences between generations that have affected the students' educational experiences in mathematics, some students did note that they had their own language struggles, with a special note given to their statistics coursework. Often this involved the particulars of wording within statistics problems and properly expressing results. Though Leticia and Ricardo had different previous statistics coursework experience – Leticia in AP Statistics and Ricardo in the dual enrollment course – both shared common language challenges.

> *Leticia*: I think having [AP Statistics] last year, from having to explain some stuff, you have to use specific wording. And like, my first language is Spanish, and I'd think about what to write, and [my teacher] would be like, you have to think about using this specific word, on my test, and I'd be like, yeah. I think the language is important to know, like, the specific terms you have to use.
>
> *Ricardo*: Yeah, I remember one thing, when writing a specific phrase, [my teacher] was always saying that people were getting mixed up with the wording, and it was like a really easy thing, but I kept getting mixed up.

Continuing the discussion on wording in mathematics in general, and probability in particular, Angel brought to point the view that, for students who are emergent bilingual learners, classes in English as a Second Language (ESOL) may not focus on mathematics vocabulary.

> [Probability] should be prioritized. It should be taught in ESOL studies… I have a younger cousin who went through the ESOL in middle school and he just got out, and I'm pretty sure he, like, doesn't know, uh, what mutually exclusive means. Prioritize the language that is used in math, please! Especially within probability… It's a lot more useful… Because it's complicated language for native English speakers. I was taught English and Spanish at the same time and I'm pretty relatively ok with both of them, and I still struggle with like the language that's used in math. It's really specific, and you need to learn it.

Angel's sentiments echo the findings of Atabekova, Stepanova, Udina, Gorbatenko, and Shoustikova (2017), who found that those in training in education and translation services

desired more background knowledge in translation of academic mathematics. Though Angel himself had not had experience in this type of class, reflecting upon his cousin's experience resonated with Leticia, who had experienced pull-out language education. She echoed the call from Angel to include subject-specific vocabulary in the lessons.

> Yeah, I agree with that because I was in ESOL… When I got to like, tougher math classes, they did ask for certain language to be used, and I was feeling like I had to learn all those terms, because I didn't know them in elementary school or middle school. I wasn't taught those specific terms. I was still learning new words. Even though they were vocab terms and basic stuff I, like, should've known, I didn't, and I felt left out in my little corner.

Here the students recognize the importance of language in mathematics but also have varying views on if their own linguistic differences make their experience different than that of their native English-speaking peers. Angel notes the struggles for both native speakers and emergent bilingual learners, while Leticia speaks more to the feeling of being "othered" by her language struggles. However, later in the conversation, Leticia expresses a strong sense of pride in her bilingualism and how, in the end, her struggles have been an asset:

> I think the cool thing about being bilingual is, um, so my parents speak more Spanish than English. So, when they taught me or helped me with any math, it was in Spanish… Up until a couple years ago, I think I did my best math in Spanish, and, in my head, they were like multiply this, and I would be like, oh, ses por ses, so like, you know? And that's how I figured it out for like myself… Everything in my mind was in Spanish. That's what my world was.

This statement by Leticia was of particular note because of the strength she found in independence and her necessity to switch languages to achieve comprehension in mathematics. The concepts of independence and perseverance were threads found in multiple categories of the *AfterMath Intersectionality Framework*.

Poverty

All seven mentors in the study identified as either first- or second-generation immigrant students so, in many cases, the themes of poverty that came out during the focus group came through the lens of their families coming to the mainland United States to seek an advancement in economic opportunity. When Eduardo spoke of his family and seeking aid from them in his mathematical studies, he expressed a perception of difference from his peers due to his background:

> I think one of the biggest things for me, is like, because my parents came from the Dominican Republic, is that if I have questions about math and I have, I don't know how to do it at home, I have to figure it out. Versus if someone's parents here [at school] are an engineer, they know everything. They know trigonometry. I can't get that one-on-one stuff from my parents.

Here Eduardo sees his peers as having a socioeconomic advantage over his, who he perceives to have had less opportunity. When he mentions that he has to figure it out, he says this without a tone of contempt but rather as one who wants to succeed. Leticia, who is a second-generation immigrant of Mexican descent, goes deeper into the educational experiences of her own family:

> They didn't have much of an opportunity to do school, so it's a lot more expensive over there and you have a lot more responsibilities, so coming from really big families, my grandparents couldn't send all of them to school. I think my mom has eight siblings. So, my grandparents couldn't send all of them to school because they couldn't afford it. So, I understand. They want my brothers and I to do good because they want us to have what they didn't.

For the mentors whose families came for economic opportunity, there was repeated expressed of a desire to be academically successful across the subjects to honor the family. This carried into the differences felt between their own current educational experiences and those of

their parents, especially in terms of the behaviorist approaches that have been seen to trend in countries with strong colonial roots.

Neocolonialism

The concept of neocolonialism exists when the educational system originated as an oppressor, usually in a colony. Then, after a nation or group gains independence, that rooted educational system remains intact, even if it is not culturally responsive. As all mentors had only attended school in the mainland United States, none had experienced neocolonialism first-hand. However, Angel noted that he felt that his own current educational experience was influenced by those of his mother, who attended school in a former colonial country noted for its behaviorist approaches.

> I come from a first-generation family so it’s mostly like, “Hey, you probably should pass and you probably should succeed!” Because my mom, over there, where she was born, she was born in Colombia, she was already bad at math, terribly so, so it was if you don’t get it, just pick up a book, get it done, it’s something you have to do. I don’t care what you have to do to pass the class, just get it done, and get it done well, at least. Find anything you can, because I can’t help you. So, you have to fend any way you can.

This discussion of independence and perseverance echoes the sentiments previously centered more in the language and poverty sectors as expressed by the mentors. The mentor students sense of being used to seeking sources of help on their own from outside sources and not relying on family at home were explained by the educational background and experiences of those family members. Therefore, the language, poverty, and family experiences with neocolonialism are strongly interwoven in the mentors’ approach to education in general. This came out even more strongly with mathematics in particular, as the approaches their families were familiar with were of different techniques than found in the students’ current curriculum.

Thus the students pushed in a way that may not be shared by their non-immigrant peers, as seen in the next section.

Student Mathematical Learning

The mentor students reported mixed experiences with their own mathematical learning. However, they were united in the perseverance in attaining mathematical knowledge, as has been expressed through the language, poverty, and neocolonialism constructs. A common theme reported by several of the mentors was the willingness to look for outside help. Paola opened up to the group about her experiences with tutors:

> Math has always been a difficult concept for me to grasp. Geometry gave me a lot of trouble regardless of the teacher. I have trouble grasping the concepts… I always have been offered help by my family and my mother even though she doesn't understand the concepts. It makes it a bit less likely that I will go off and ask for help. Because I've been offered help from tutors and private institutions and places created to help students get better at math. And that just gets me to the point where I know what I'm looking at and can see a problem by itself.

Paola has been seeking outside tutoring for years in order to help with her math skills. She cites that she has taken advantage of the free tutoring services within her schools first. When that wasn't enough, despite socioeconomic disadvantage, she has attended paid tutoring establishments that specialize in mathematics as well. Angel echoed struggles with mathematics and, not wholly unlike Paola, sought an avenue outside his regular school to succeed. For him, though, this pathway for change came in the form of summer school.

> I personally used to be really bad at math until recently. I went to summer school for geometry. And then I came back and got the award for my Algebra II class as top student. So, if you ever want to see a difference between teachers, that's always fun. So, I'm pretty good at algebra now, hopefully. I still remember a lot of concepts from geometry. That's pretty fun for me. I like tutoring students in other classes. It's just fun.

Angel here brings up a theme that came with the experience of many in the group with student mathematical learning: the perceived importance of the classroom teacher. The students repeatedly cited the importance of their classroom teacher in their feelings of strength in mathematical skill and ability to be successful. Although they have different backgrounds, with Andres having Colombian heritage and Mia identifying as Argentinian, both felt that teachers were important in their chance to succeed.

Andres: Yeah, I think math is the most teacher-dependent core subject, like earlier how I mentioned that I struggled with some, a teacher who doesn't really teach but leaves you with your own problems and examples leave you kind of feeling stranded and you may sit there for half the class and not know what is going on. But if you have a good teacher, then everyone has a fair and even opportunity to learn it.

Mia: Yeah, I also agree that math is always easier when I had a good teacher. I struggled a lot otherwise.

For Eduardo and Leticia, the experience with the teacher greatly influenced their behavior outside of the classroom. They speak of independent learning previously mentioned in the vein of the influences of poverty and neocolonialism, but what drives them to this independence is interestingly opposite. For Eduardo, an engaging teacher pushes him but for Leticia, her outside involvement came as more of a necessity.

Eduardo: For me personally, I think it's always really been algebra. I'm not good at it. It's always been hard. So, I have to find a specific person to learn it. If a teacher isn't really putting in the effort to teach a student. And if the teacher is someone like, I really don't want to be here anyways so I'm just going to teach the information, I'm not going to be getting as much as someone who keeps me intrigued in it, because then I want to learn it and I want to figure it out outside of school.

Leticia: Yeah, I think I agree with him because I had that same experience during geometry. I felt my teacher wasn't really into it. So, by the middle of the

year we formed our own group to study and had study sessions to try to get through the class.

Leticia's description of creating her own outside group to pursue mathematics as a way to informally tutor each other parallels Paola's earlier mention of seeking outside tutoring. Angel's experience in summer school drove him to be an unofficial tutor. For all of these students, despite different backgrounds, a common thread is seen in the persistence in learning outside of the formal classroom setting.

When it comes to mathematical learning within the specific realm of probability and statistics, the mentors did cite an affinity for the topics, in spite of the aforementioned linguistic challenges that the problems have posed. The discussion turned lively when discussing statistics coursework in their perception of its immediate usefulness and perceived connection to the concrete in their lives.

Eduardo: Yeah, [probability is] definitely more like, real world stuff. They'll slap a quadratic equation on you and you're like, when the hell am I going to use this? I'm never going to have to solve a quadratic equation to get my coffee, but probabilities are like things you are going to put into practice and know you'll use it in the real world.

Paola: It's easier to tie associations with it. It's much easier to grasp what the numbers in front of you actually mean.

Angel: Because they actually *mean* something this time!

This idea of finding meaning within probability and statistics and the importance of context has been seen in classrooms in the Global North but has been rung especially true in the Global South. The abstraction of mathematics has been cited for many years as one of the struggles in Global South learning (e.g., Gay & Cole, 1967). As problems in probability and statistics are almost always given in context, this often rings more true linguistically and culturally than the

idea of "math for math's sake." Even with the reported language struggle, the students repeatedly discussed enjoying the purpose they found within the topic.

Summary of Mentor Pre-Intervention Focus Group Interview

The seven mentor students expressed, as a whole, common themes of struggles with language in learning but also saw the beneficial side that their bilingualism affords them. As a cohort of students with first- and second-generation immigration status, there were many similarities seen in their approaches to mathematics being fueled by perseverance and expectation to do better for their families who may have struggled with socioeconomic disadvantage and lesser schooling conditions or opportunities. When it comes to probability and statistics, this group finds an affinity and meaning in the topic and enjoys the real-world connection that they tend to find with perceived ease.

Mentee Pre-Intervention Focus Group Interview

The mentee pre-intervention focus group interview took place on August 20, 2019. The interview lasted approximately twenty-two minutes in length, and, similar to the mentor interview, all mentees were present and seated round-table style. They were asked the same questions from the Probability in the AfterMath Interview Protocol (Figure 3 in Chapter 3) as the mentors. As was the case with the other focus group, these student responses were audio recorded and later transcribed by the researcher.

Using the *AfterMath Intersectionality Framework*, the student responses were hand-coded as to the theme falling into the overarching theme of language, poverty, neocolonialism, student mathematical learning, or natural disaster interruption. In the case of the mentee focus group, the discord among the members was more direct to the question at hand, and the

responses were more simply categorized into the framework than was the case with the mentors. Still, within the categorizations, two rounds of subcategorization occurred within each category. The results of the focus group interviews by category of student response are analyzed within the framework as follows. It is important to note that, in the case of the mentees, interview responses came in both English and in Spanish during the course of the conversation. In the case of the Spanish responses, the original Spanish is presented with English translation to the side.

Language

Although the original intention of the study was to have seven mentors and seven mentees, one mentee was unenrolled from the high school that served as the host of the study in order to attend a different district high school that offered more intensive English language services. She did not get to the point of participation in the interview process and thus was removed from the study, but her language struggles are mentioned here as they are in line with the theme expressed by the six mentee students who did complete the study.

The students expressed that language of instruction has been one of the biggest challenges since beginning school in the mainland United States. This struggle was mentioned regardless of if the student's previous language of instruction was Spanish, English, or a combination of the two. The main theme of the struggle came in understanding the teacher. Carlos, whose schooling was formally conducted in English, stated the following:

> So, when you're here, your second language is English. So, you won't understand, like, 100% what the teacher is saying. So even though you can speak it and talk it with someone, you won't get it the same. Like, you won't understand it the same way as if you have somebody in your first language.

This speaks to the fact that, even if the education is conducted in English in Puerto Rico, the way in which the English is expressed is different when everyone in the room, including the teacher, is a second language learner. Several students felt the time where this was seen prominently was in the speed of expression and instruction. This was especially expressed by Jose and Jesus.

Jose and Jesus are sixteen-year-old identical twin junior males currently enrolled in Algebra II. They lived in Puerto Rico their entire lives until Hurricane Maria destroyed their school and home. After the hurricane and a self-reported four-month interruption, they attended a nearby school where students were combined from multiple schools in the area. They describe the new school as being very overcrowded and, in July 2018, the family moved to Florida. In all Puerto Rican schooling for Jose and Jesus, the language of instruction was Spanish. Though Jose states that, in general, English is “not a big problem,” Jesus feels learning for him at his new school is “a little complicated” as he tries to get accustomed to the language difference. In terms of speed and language of instruction, Jose and Jesus state the following:

> *Jose*: That’s probably been the biggest concern. English and speed. It’s all in English. Some words change.
>
> *Jesus*: The teacher that we have… Can I talk in Spanish?
>
> *Researcher*: Yes, you can talk in any language you like.
>
> *Jesus*: ¡El maestro que ahora dice las cosas demasiado rápidas! La que nosotros teníamos nos explicaba como en juego.
> *The teacher we have now speaks very fast! The one we had before explained things with games.*

Outside of the speed with which the English is used in the classroom, Genesis, the sole female mentee in the study, cited the language within the mathematics class itself in terms of vocabulary and mathematical translation as a challenge. All of Genesis’s previous schooling was

conducted in Spanish, and she learned English from her mother and from watching television. Genesis lives with her mother and speaks both English and Spanish at home.

> From what I remember, I never had word problems in Puerto Rico. It was just like divide, and then do what they ask you to. And then I came here and I was like, what is this? I didn't know what a word problem was until I came here but I was like, well this is interesting, but it wasn't bad. It was weird. Obviously, you know some of the terms. It was like, you know add, subtract, and divide. But then there's like, quotient and product, and then there's like, they put them all in a fancy little sentence and I'm like, ok, this makes no sense, and you're just sitting there and trying to read it over and over again and you know there's a number 3 in this equation, and that's it. It was kind of weird to start from not having any word problems to having to jump in and be expected to do all of that. To pull items from word problems and put them into an equation in a way you can actually solve it. Like that was really interesting to learn.

Genesis's perception was unique in that it was not commented upon by any of the other mentees. Although it may be part of her memory that she does not recall having word problems, she felt certain about multiple differences in her standard of education in Puerto Rico when compared to the mainland United States. Many of these differences were rooted in issues one would find in association with poverty in the educational sector. As schools in the United States with 75% or higher Free and Reduced Lunch, have shown significantly lower mathematics literacy averages than those which do not have this designation, and Puerto Rico has the second highest Free and Reduced Lunch percentage in the country at 91.9%, the possible effects of poverty and mathematical learning cannot be ignored in this case (Ed.gov, 2019; NCES 2019).

Poverty

The mentee cohort came from a mixed background of educational experiences in their former Puerto Rican schools. Carlos attended a private school where the language of instruction was English. Jose, Jesus, and Luis attended private schools where the language of instruction was Spanish. Hector attended a public school where the language of instruction was Spanish, and

Genesis began at a public school in her primary grades but then later was switched by her family to a private school. The students were quick, however, to comment upon how private school attendance did not, in their opinions, mean that the family was necessarily wealthy. Instead, the private school attendance was about a value of education. Genesis put her experience and change in schooling in context:

> When I tell people here I went to private school, it wasn't because I was rich, it was because I needed someone to be in the classroom and teach me and needed the confidence they would be there. It was bad.

This feeling of a need to have a different schooling experience in order to have opportunity speaks not only to the common themes of poverty associated with public schools on the island but also in the neocolonialism of the school structure, as will be discussed in the next thread. However, these feelings of concern about a substandard education where not limited to the students' experience in public school. Jesus, a sixteen-year-old junior currently enrolled in Algebra II, had his entire schooling experience before coming to the mainland United States in private school, and he expressed a feeling of being behind, stating, "Yeah, everyone learned [my current Algebra II topic] in kindergarten and, yeah, I learned it in Puerto Rico in 5th grade."

While this disparity is likely an exaggeration of the curriculum speed of the mainland United States, differences in the grade levels of content coverage were noted in Chapter 2 when comparing the Puerto Rico Core Standards to the Common Core State Standards. Regardless, Jesus's perception of his mathematical preparedness due to a substandard education is what speaks to concern. The difference in achievement, previously highlighted in the literature review, is one of the strongest disparities seen between the Puerto Rican and mainland mathematics education experiences.

Neocolonialism

Although under similar standards to the mainland United States educational system, the approaches in the Puerto Rican schools often more closely resemble what one would find in many countries of the Global South that were previously colonized by the Global North, as was discussed in the literature review. The students expressed feeling strong differences between their schooling experience between Puerto Rico and in Florida so far, with many feeling a positive shift, especially with teacher interaction. A common problem in the Global South and many former colonial educational systems is teacher absenteeism and, in many regions, a substitute teacher is not a concept in place. Genesis experienced teacher absenteeism from an early age first-hand:

> I went to a private school from first grade on. Before that I went to a public school. And the teacher literally didn't come, like, every Friday she would miss. So then, if you know anything, they would just say like, call your parents, your teacher didn't come, you gotta pick up your kid. That was it. And [changing to private school] wasn't about like, you know, giving me a higher level of education. It was about giving me a stable education and an opportunity to learn something.

In addition to absenteeism, harsher teacher approaches in terms of behaviorist models and a more forceful demeanor are often noted in schooling systems rooted in colonialism. Luis specifically spoke of how he felt, in the short time since arrival, pleased with the differences in teacher interaction he was experiencing in the mainland in comparison to his previous schooling in Puerto Rico, stating, "Yeah, it's easier here than over there. Over there, they screamed at me a lot. Over here… the teachers are really nice in this school."

Hector and Genesis echoed surprise and positivity in terms of teacher interaction and the ability to get help and ask questions in the classroom setting.

Hector: My experience has here actually been pretty well because there are a lot of nice teachers here. My experience here has been pretty good.

Genesis: There's a lot of help here. People are willing to help. At least for me, at my old school, there wasn't a lot of help. They just gave you the work, you were expected to do it, and that was it. It wasn't really like, you have a question? They don't really work through it with you. It was like, there you go [laughs].

Although the students reported generally positive views on the educational differences since arriving to the mainland as far as interactions with teachers, the mentees did note that, in the case of some teachers, they did feel sensitive to stereotypes about themselves and their experience coming in.

Genesis: Some people may have assumptions about the level of education over there versus over here, so…

Hector: Sometimes what the teacher says here can be a little confusing. Or some may judge you for your race. Some, not all.

The feelings of the students at being stereotyped could be due to their educational backgrounds but also to the perceptions of poverty in Puerto Rico as well as the linguistic differences of the new students. Both of these stereotypes, and their impact on student learning, have been noted by multiple researchers (e.g., Guitérrez , 2008; Ocasio, 2009). It is impossible to know from the student report which piece of their identity is most linked to these judgements, whether real or perceived, as they all intersect to the unique situation of these displaced students. This intersection is seen quite prominently in the mentee's perspectives about their mathematical learning, as is discussed in the next section.

Student Mathematical Learning

When considering their mathematical learning in general, the majority of the students were relatively quick to affirm the similarities between the content of what they are learning currently and what they learned during their time in school in Puerto Rico. Jesus feelings received a general agreement from the cohort:

> *So it's the same, like… es lo mismo. Es la misma matemática, pero allá nos daban diferentes temas y eran el mismo lenguaje.*
>
> *So it's the same, like… it's the same. It's the same mathematics but over there, we had different topics and it was in the same language.*

In terms of challenges outside of the language of instruction, there was a common theme related to the struggle to remember definitions. Both Genesis and Hector stated that this was their biggest point of trouble at the moment, because the differences in the vocabulary were difficult to remember. As Jesus and others recognize that "it's the same mathematics," albeit at a possibly different level, it is likely that these struggles are primarily rooted in knowledge gaps and trying to account for them in a new language. Luis additionally admitted to spacing out and finding it difficult to concentrate as the definitions were stated and being overwhelmed by the sheer amount of them to commit to memory. Jose echoed their sentiment, citing the amount of vocabulary experienced last year in geometry making him pleased to be "back in algebra."

When discussing their experiences in learning probability and statistics, for most, the concepts are new in their curriculum and thus the answers did not often have the same depth as what was stated by the mentors, who all had previous statistics-specific coursework in their schooling. Thus, when approached with the question about what they think when they think

about probability and statistics as compared to other mathematics, the student conversation was more filled with definitions or vocabulary as opposed to application.

> *Carlos*: [Probability] is what I'm studying now. Probability means you have a certain chance you get to do something or get something, and statistics is… Some stats that has been recorded for several days or a certain amount of time. I think that's it.
>
> *Jose*: Yeah. Geometry is more like figures, and statistics are more like focused on numbers and percents and all that.
>
> *Genesis*: Real world problems and examples. Things that are based on actual information that we could actually use.
>
> *Jesus*: I don't think I've taken statistics…

At this stage, the majority of the mentees are entering Algebra II, and thus will have larger units of probability and statistics included in their curriculum. However, according to the curriculum standards of the Common Core State Standards and the corresponding Puerto Rican Core Standards, it is apparent that statistical topics have been a part of the curriculum for far longer. The perception of the students, however, is telling going in to the intervention and aligns with the demonstration of knowledge seen in the results of the pre-intervention assessment, as discussed in the Quantitative Analysis section.

Natural Disaster Interruption

Although the possible reasons for the lack of student familiarity with concepts in probability and statistics are in multitude, one common theme experienced by all students in the cohort was the interruption in their formal education due to Hurricane Maria. The amount of time the students were out varied greatly, from just under one month to five months. For those who did experience a return to schooling in Puerto Rico before leaving for the mainland United

States, though, school did not resemble the experience prior to the hurricane. Carlos spoke of the destruction of his school and the change in the student population upon his school's reopening after three months:

> We lost a lot of buildings and things still aren't rebuilt. So, we had to go into a smaller building and fit all the classes in there. Then, because their schools were destroyed and couldn't come back, two other schools were with our school. It was… yeah, it really didn't work. The teachers used to teach us all in English. Then when the new students came, everyone was at a different place and the teachers tried to switch back and forth between English and Spanish all the time. It was just kind of a mess. It didn't work. And it was too many people in there together. And no one was at the same place.

Due to the struggle with no end that could be seen in the near future, Carlos moved from living with his mother in Puerto Rico to Florida, where his biological father resides. This semi-permanent displacement is not uncommon, as was noted in the Hoeppe study (2016). Jose and Jesus's entire family moved for similar reasons but also for the whole family to have a new beginning. Jose expressed a feeling of struggle and being behind from the gap in education:

> It's been a little bit hard here. Maybe because we were behind. And when we came here… So, the hardest thing that happens to me is every student in class knows what is talking about, except me. But they have taken it before two years ago when we didn't. When [the teacher] is teaching, my brother and I don't know what he's talking about and everyone knows.

This sentiment of being behind the rest of the population was shared by a lot of the group and was seen as a point of frustration. This idea directly aligns with what was discussed by Spencer, Polachek, and Strobl in their large-scale Caribbean study about the gap in mathematical gains after students returned to school following hurricane interruption (2016). However, with the notable exception of Genesis, none of the cohort mentioned reaching out to the teachers or tutoring services offered by the school for aid.

Summary of Mentee Pre-Intervention Focus Group Interview

The cohort of the six mentees shared a common theme of struggles in the language of instruction of their mathematics education, especially in the speed of delivery, regardless of the language of instruction of their previous education in Puerto Rico. Despite many of the students having received private school educations before coming to Florida, themes of poverty and neocolonialism governed their education, including instances of teacher absenteeism and the perception of harshness. At this point in their academics, the students have a more general concept of what probability and statistics entail, and many have perceived gaps in their formal education. With time out of school due to Hurricane Maria ranging from approximately one to five months, there is a gap in knowledge across the board that stands for an opportunity for an intensive intervention.

Mentee Post-Intervention Focus Group Interview

The mentee post-intervention focus group interview took place on September 25, 2019. The interview lasted approximately twenty-eight minutes in length, and, similar to the pre-intervention interviews, all mentees were present and seated round-table style. They were asked the questions from the Probability in the AfterMath Interview Protocol but also to offer any feedback and reflection on the intervention of the process as a whole. As was the case with the previous focus groups, the responses of the mentees were audio recorded and later transcribed by the researcher.

Using the *AfterMath Intersectionality Framework*, the student responses were again hand-coded as to the theme falling into the overarching theme of language, poverty, neocolonialism, student mathematical learning, or natural disaster interruption. In contrast to the pre-intervention focus group, there was far more interaction between the mentees in the

conversation and crossover between categories of response within the framework. As before, two rounds of subcategorization occurred within each category. During this particular focus group, all mentees responded in English.

Language

The mentees demonstrated shifts in language through the course of the intervention in terms of language of communication and written expression. In the first task as the mentors and mentees were meeting for the first time, the communication was primarily in English. The exception in this was Jesus, who often relied on his twin brother Jose for translation and was reluctant to speak out. When the second task came, Jesus started communicating with his mentor Ricardo in Spanish and through the third task. This reflected in Jesus' writing, when he would use any verbal descriptors regarding probability exclusively in Spanish, as seen in an example response from the sixth question of Task 3, *Missing the Mofongo and the Arroz con Gandules*, below in Figure 24:

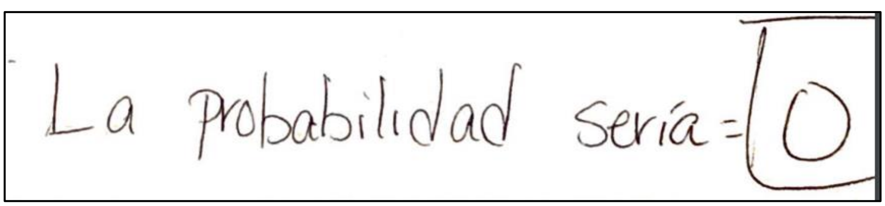


Figure 24: Jesus' response to Task 3 Question 6

Although this was not the correct result, as Jesus had indicated the probability of three students choosing the restaurant instead of two, this verbalization shows a marked difference in his expression, which had been previously lacking. By the fourth and fifth tasks, however, the communication between Ricardo and Jesus was almost entirely in English. With this too, Jesus' written portions of his communication shifted to English. Although his English showed some

mistaken words, as seen below in the interplay of the words “chance” and “change,” he was actively communicating his results in English at this time, as seen in Figure 25 below:

31.3 + 12.1 + 4.7 + 5.2 + .3 + .2 = 53.84 % chonce

18.2 + 10.9 + 2.2 = 31.3% change

Figure 25: Jesus' responses to Questions 1 and 3 in Task 4

In Task 5, where students had the opportunity for open-ended communication, Jesus again chose to answer the question in English, though he expressed that his language of preference for peer interactions is primarily Spanish. Jesus’ response to the first question of the final task is seen in Figure 26 below:

I identify myself different from the others because im puertorican, eventho most of the people in this school are puertoricans. We talk spanish all the time and like to talk to each other and share. We are 5 in our house

Figure 26: Jesus' response to Question 1 in Task 5

Speaking of his changing usage of English, Jesus succinctly said, “Yeah, my English, it’s better. Time and talking helped. Now I know the words and when to add, subtract, multiply… Math was going bad. It’s going better now.” Jesus spoke more freely and openly in the post-intervention interview than previously. In comparison to the pre-intervention, he chose to speak entirely in English when answering the questions.

Genesis, who had previously discussed struggles with word problems, mentioned increased understanding of the language of world problems in terms of interpretation.

Consistently the most vocal of the mentees, she would often talk through problems aloud with her mentor, Paola, but chose to do so almost exclusively in English after the second task. She stated that since her normal classwork is in English, she wanted to use English as much as possible. This echoed Hector's feelings in Task 4, when he requested to only receive English versions of the tasks. For Genesis, she reported an increase of understanding with the language of problems, saying, "I understand that it is essential to pay attention to the wording! I would mess that up before. I still do, but I know what to pay attention to." Genesis additionally reported that, in her Algebra II class in which she is currently enrolled, that she now feels her problem-solving skills have increased because she is slowing down her reading and knows what details are important.

Poverty

In the pre-intervention focus group interview, most of the discussion around poverty was rooted in the situation of the mentee's schooling. They discussed subpar educational practices that they had encountered, as one may find in many areas of lower socioeconomic status in the United States, though certainly not limited to those. In the post-intervention focus group, however, the conversations related to poverty took a very different shift, as the mentees became reflective about their lives in Florida and how what they thought was temporary is looking more permanent, especially in the cases of Carlos, Jose, and Jesus. When Carlos moved from Puerto Rico, his mother stayed on the island. At the time of the study, he was residing with his father, stepmother, and two siblings.

> I've told my mom I am ready to go back. I want to graduate with my friends I grew up with. She says it's still too bad for me to go back, though, so I'm probably going to stay. My school is still not good [in Puerto Rico]. So for now I am staying.

Carlos' school saw severe physical destruction due to the storm, and he would get occasional photo updates from his mother. Two years later, the majority of the multiple building school is not ready for full student re-entry and, as Carlos has described it, his friends back in the school are in large combined classes.

In the case of Jose and Jesus, their entire nuclear family moved from Puerto Rico to Florida as a unit. Still, they spoke of their desires to return to their home in Puerto Rico and the resistance of their family to do so.

> *Jesus*: I want to go back. I miss home. But my mom says… She says it's better for us here.
>
> *Jose*: Yeah, like, the opportunities here. There's more for them to be able to do here than back home.
>
> *Jesus*: Yeah, we are staying.

Jesus and Jose have reported making friends. In Jose's words, he has "met some cool people" through the intervention, and Jesus and Carlos have discussed spending free time together both during school and after school hours. Even with this, however, the pull for home is strong. The recognition that home does not have the same opportunities for their family and them in terms of schooling, though, has both young men realizing that this home is likely to be their new home. Their words now with the talk about staying for opportunity ring far more closely to those of the mentors in the pre-intervention interview, where much of the poverty-centered discussion was about the family sacrifice and immigration to seek out advancement in the mainland United States.

Neocolonialism

The pre-intervention focus group interview saw much discussion around the colonially-rooted relationship between teachers and students in the classrooms of Puerto Rico from the perspective of the mentees. This often led to the students being more quiet in class for fear of being "yelled at" for asking a question and only considering solo work as the way to success. Here, the mentees discussed the differences they saw in how learning took place during the *AfterMath Intervention.*

> *Genesis*: It was fun! We actually got to move and talk and work with each other and it just felt easier. More fun.
>
> *Jose*: I got to meet people and talk to them and then understand more.

While Genesis and Jose recognized changes in educational approaches in collaborative learning during the intervention, Luis used the connections made to realize how to ask for free help being offered at the school. Luis' mentor was Mia. However, as Angel's original mentee, Gabriela, left the school of study for reasons additional language services, Angel took on the role of rotating mentor in the case of one being absent. If none was absent, then he would assist where needed. Angel and Luis developed a strong bond, and as Angel is involved in multiple clubs and services at the school, he became a resource point for Luis.

> Angel helped me a lot. Mia too, but Angel told me where to go. I can get help after school now and at lunch. So, I'm going. Not just for math. There's a lot of help here. Angel said I can't be like him and get stuck in summer school!

Angel's summer school experience and the change it brought about in him was a topic that came up often between Angel and Luis and, at the time of the post-intervention, Luis had begun attending tutoring and joined a school club to meet more people. He reported this was his first time doing so.

For Jesus, the change in realizing the classroom culture of the school led to him becoming more participatory and speaking out more in his own classes. He revealed, “I talk more now. I ask questions. It’s ok to ask questions.” This recognition represented a large change for Jesus, who not only often has relied on his brother Jose for translation but, as he and Jose have identical class schedules, there has not been a large incentive to speak out. Jesus stated that he now works with others and asks questions of his teacher and group members, especially in his science lab.

Student Mathematical Learning

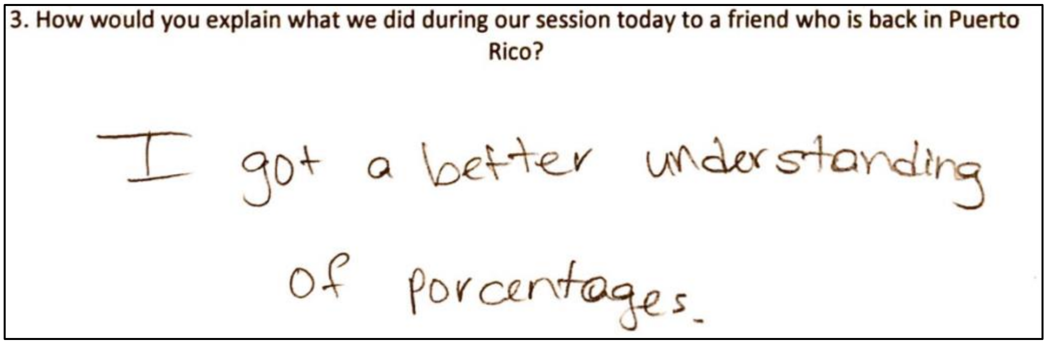
Though students discussed mathematical learning in the previously veins in the context of language with the wording and growing accustomed to mathematics in English and neocolonialism in terms of behavior and interaction in the mathematics classroom, there was also discussion of the feelings of increased understanding that occurred in mathematics due to the intervention.

Jose: [During the intervention] I learned more about math and how different problems solved. This was a good class. I had some cool tutoring and I met some new people.

Hector: Yeah, I understand probability better now. I always struggled in middle school. It’s better now.

Genesis: I don’t feel weak or so lost… For now (laughs)!

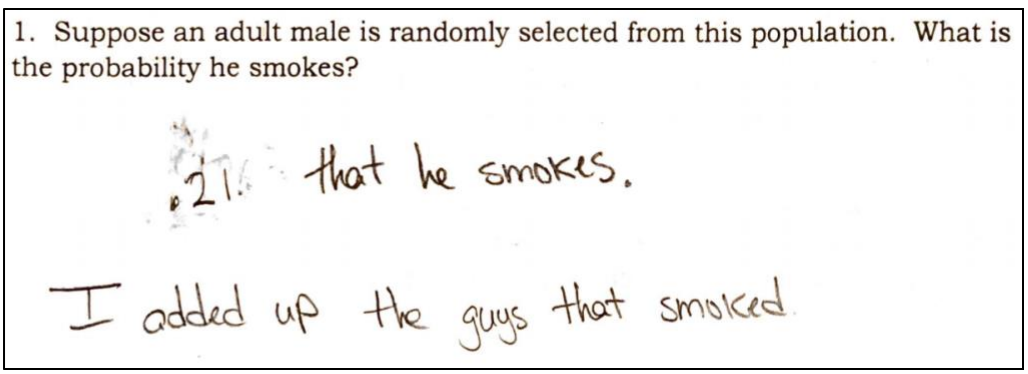
This was not the first time Jose had expressed the feeling of understanding more mathematical concepts. In the post-task reflection for the Task 1, *Home Away From Home,* he discussed increased confidence with percentage calculations, as seen in Figure 27:


3. How would you explain what we did during our session today to a friend who is back in Puerto Rico?

I got a better understanding of porcentages.

Figure 27: Jose's post-task reflection for Task 1

Indeed, Jose did show an improvement in the understanding of decimals and percentages. When Jose took the post-test, not only was he performing well, but he chose to use English verbal explanations of his work interspersed with calculations, as seen in the example in Figure 28 below:


1. Suppose an adult male is randomly selected from this population. What is the probability he smokes?

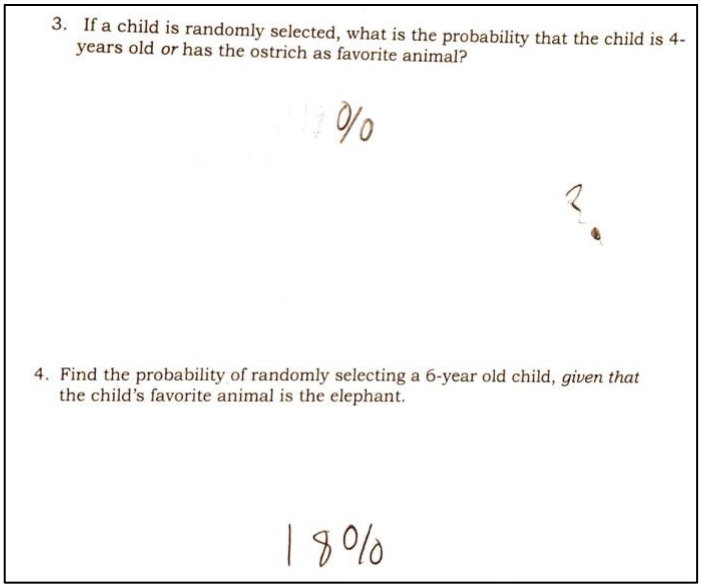
.21 that he smokes.

I added up the guys that smoked.

Figure 28: Jose's response to Question 1 of the post-test

Jose's self-interpretation at increased understanding was reflected in his post-test results. When looking at Jose's improvement through a matched pairs *t*-test, Jose's score showed a statistically significant increase across the board ($t(6) = 3.24, p = 0.018$).

Hector's sentiment of mathematics being "better now" was consistently reflected in the trajectory of his work throughout the intervention. Hector scored the lowest on his initial pre-test among the mentees, with most of his answers being blank or superficial attempts, as seen in the example in Figure 29 on the following page:



3. If a child is randomly selected, what is the probability that the child is 4-years old *or* has the ostrich as favorite animal?

%

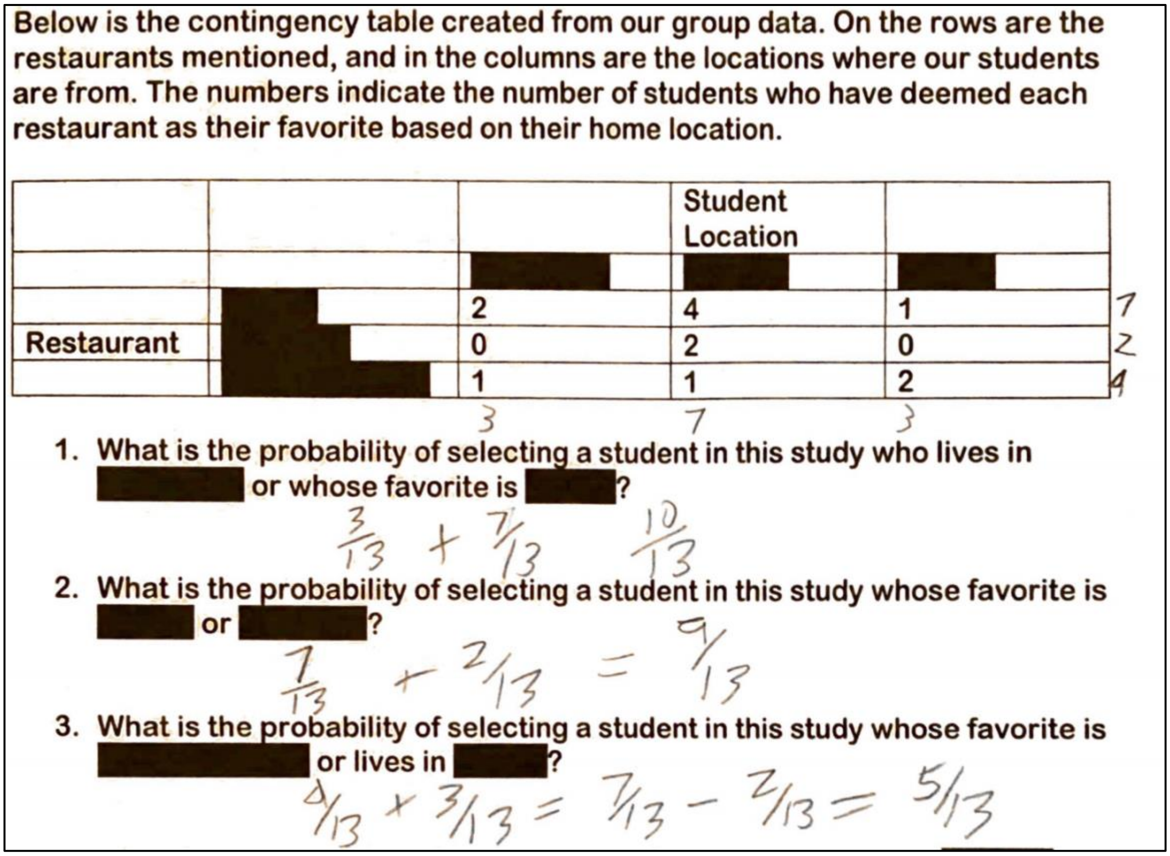
?

4. Find the probability of randomly selecting a 6-year old child, *given that* the child's favorite animal is the elephant.

18%

Figure 29: Example page from Hector's pre-test

Hector started to build momentum early on in the first and second tasks, showing more work and understanding each time. By the third task, where Hector requested to start receiving only the English version so that he could better match the language he was seeing in his class, his answers showed a much higher level of sophistication than previously witnessed, as can be seen in this example in Figure 30 on the following page:



Below is the contingency table created from our group data. On the rows are the restaurants mentioned, and in the columns are the locations where our students are from. The numbers indicate the number of students who have deemed each restaurant as their favorite based on their home location.

			Student Location		
		[redacted]	[redacted]	[redacted]	
	[redacted]	2	4	1	7
Restaurant		0	2	0	2
		1	1	2	4
		3	7	3	

1. What is the probability of selecting a student in this study who lives in [redacted] or whose favorite is [redacted]?

$\frac{3}{13} + \frac{7}{13}$ $\frac{10}{13}$

2. What is the probability of selecting a student in this study whose favorite is [redacted] or [redacted]?

$\frac{7}{13} + \frac{2}{13} = \frac{9}{13}$

3. What is the probability of selecting a student in this study whose favorite is [redacted] or lives in [redacted]?

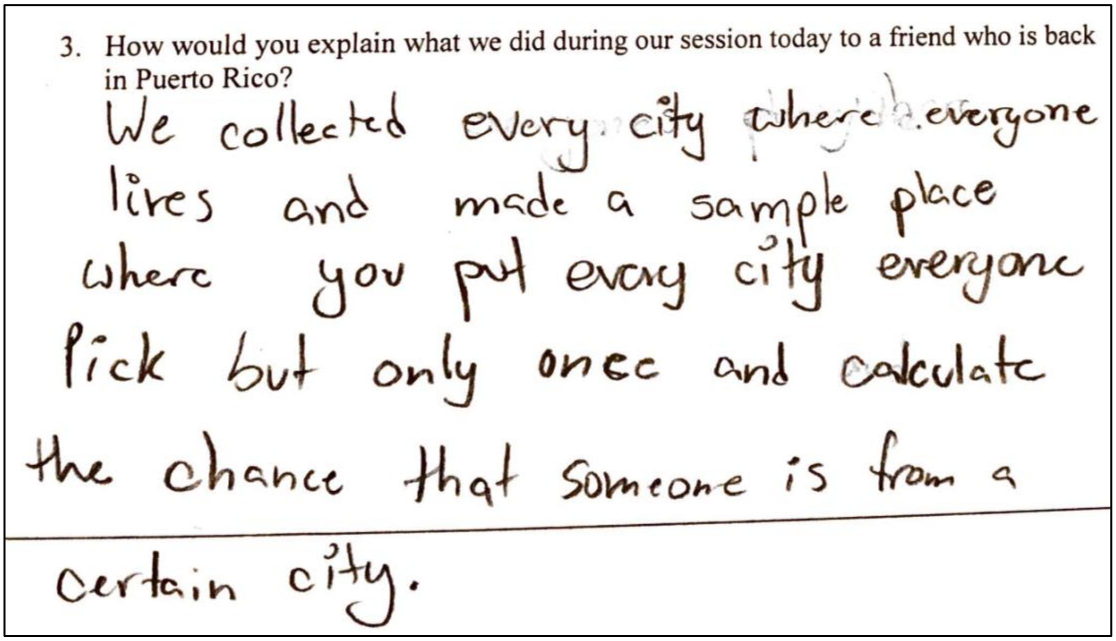
$\frac{4}{13} + \frac{3}{13} = \frac{7}{13} - \frac{2}{13} = \frac{5}{13}$

Figure 30: Hector's responses in Task 3

Not only here can Hector's understanding of the operations be witnessed, on the outsides of the contingency table itself can be seen the places where Hector filled in his totals, a suggestion the researcher witnessed coming from his mentor Leticia, as she mentioned it helped her "keep track of everything." Indeed, Hector's pre-test to post-test performance saw a statistically significant increase ($t(6) = 3.29, p = 0.018$), as he went from being the lowest scoring student in pre-intervention to the second-highest at post-intervention, behind Genesis.

In Genesis' case, she often expressed previous struggles in terms of understanding what was being asked of her. Often the most talkative of the mentees, she used verbal explanations in

her written work as well in post-task reflections. Here in Figure 28 in her post-task reflection for Task 1, she describes the process of creating and using the sample space:


3. How would you explain what we did during our session today to a friend who is back in Puerto Rico?

We collected every city where everyone lives and made a sample place where you put every city everyone pick but only once and calculate the chance that someone is from a certain city.

Figure 31: Genesis' post-task reflection for Task 1

Though the vocabulary may not be perfect (i.e., sample place instead of sample space), the understanding of the process of creating a sample space, including the idea of having one item in the space per participant, as seen with the phrase "you put every city everyone pick but only once." This creation of sample space by the students to increase understanding, as recommended by Chernoff and Zazkis (2011) among others, was viewed as effective by Genesis upon reflection.

Genesis had also been vocal about her struggles in knowing what operations to perform and their correlation to the problem at hand. In her post-task reflection after the Task 3, *Missing the Mofongo and the Arroz con Gandules,* she expressed a new-found understanding of the compound probability calculations, as see in Figure 32 on the following page:

1. What, if anything, do you feel you understand better after today's task?

I understand that when adding the totals of two different rows and groups subtract the correlated number.

Figure 32: Genesis' post-task reflection for Task 3

Here Genesis is referring to the understanding of the addition rule calculation from a contingency table. Although Genesis' matched pairs t-test of pre-test to post-test should an increase, it was not statistically significant $(t(5) = 1.99, p = 0.094)$. Even with this, her expressed increase of confidence "for now" in itself is viewed as a positive finding. The positive impact on self-efficacy reported by Jose, Hector, and Genesis in this program echoes that of previous newcomer programs studied (e.g., Spaulding, Carolino, & Amen, 2004).

It is important to not overstate that one intensive intervention time can increase student mathematical learning permanently, as Genesis astutely pointed out with her "for now" statement. Though bilingual mathematical interventions of this nature have shown statistical significance in pre- to post-assessment results and increased student efficacy in other studies as well (e.g., Gerena & Keiler, 2012), it is important to note the possibility for long-term effects of the intervention. The mathematics skills regained during the time and the increased student confidence to pursue mathematics had a profound effect on Carlos, who has desires to enter the military after graduation.

> For the ASVAB, I know I need 32 points. That's what I was going for. But it's better if I get 40 or 50. I think I can get there. Then I can do what I really want in the Coast Guard. I know how to reason and ask for help when I don't.

The ASVAB, or Armed Services Vocational Aptitude Battery, serves as the examination for Americans entering the armed forces to help determine for what positions they may be qualified to train. The test includes many topics in mathematics and quantitative reasoning, and Carlos is looking ahead for his future.

Natural Disaster Interruption

The students spoke to the overarching theme of natural disaster interruption as stated in the poverty section, when they expressed a desire to go home but also have realized that their displacement due to the circumstances of Hurricane Maria has brought them to a more permanent stop in life. However, Carlos went deeper in his discussion of the effects of the storm. Still in strong communication with his mother in Puerto Rico, he sees an avenue to assist those back home by being in the frontline of the seas.

> I could never be a teacher. I can't… I don't do people like that. But the Coast Guard – the Coast Guard is a way of helping. If I take the ASVAB next October or November, then I can be in the Coast Guard in June and graduate by August and start helping.

Carlos' wish is to be stationed in Puerto Rico. As the Atlantic hurricane season runs from June through November, with the peak times being mid-August to late October, Carlos is expressing a desire to help at the time and place when the next storms would come to pass. The natural disaster interruption is more than an educational circumstance for Carlos – it is part of his identity.

Summary of Mentee Post-Intervention Focus Group Interview

The cohort of the six mentees shared promising gains in their understanding of the language of mathematics and increased comfort in using English in the mathematics classroom.

Students reported an increase in confidence in their probability skills in the setting of the intervention, and this was reflected in their increased mathematical maturity and expression in their tasks and post-intervention results. An unexpected positive consequence of the intervention was the change in the mentees in terms of comfort in their traditional classrooms, adaptation to classroom culture, and willingness and awareness of seeking outside help for academic and personal enrichment. An increased sense of belonging was reported, but many of the mentees were still keenly aware of their identity as displaced persons in a place that does not feel like home. However, promise in the use of mathematical study techniques to gain knowledge for future career goals rooted in personal experience in the effects of natural disaster was seen as a major positive outcome of the study.

Mentor Post-Intervention Focus Group Interview

The mentor post-intervention focus group interview took place on September 26, 2019. The interview lasted approximately twenty-two minutes in length, with all mentors present and seated round-table style. As was the case with the mentees, they were asked the questions from the Probability in the AfterMath Interview Protocol but also to offer any feedback and reflection on the intervention of the process as a whole. The responses of the mentees were audio recorded and later transcribed by the researcher.

Again, using the *AfterMath Intersectionality Framework*, the student responses were again hand-coded as to the theme falling into the overarching constructs of language, poverty, neocolonialism, and student mathematical learning. The conversation between the mentors was interactive between the students as it was in the pre-intervention focus group. Two rounds of subcategorization of coding occurred within each category. However, during this time, the students spoke primarily of issues of language and student mathematical learning. There was one

case of an item mentioned by Eduardo tied to poverty by previous his own previous expression, as will be discussed below. Neocolonialism was not a theme found in this focus group interview. Previously, discussion around neocolonialism was rooted in family experiences. As this discussion was mainly focused on the intervention experience and not student background, for this group, this thread is eliminated from the post-intervention analysis.

Language

In the case of language, the mentors discussed their surprise and adjustment as, since the group had experienced schooling in the mainland United States, this was the first time they were speaking in Spanish regarding mathematics in a semi-formal setting. This switch provided some initial challenges for the mentors as they navigated their explanations away from their own expression and vocabulary in how they had been formally instructed.

Eduardo: For me it was a challenge because, a lot of stuff, I wasn't sure how to say it in Spanish. Like, sometimes you look at it and you're like, do I just have to, you know, Spanish it up a bit?

Leticia: Yeah it was weird because my first language was Spanish, then I learned English, and then being here it was like, now I have to learn some of these terms in Spanish.

These feelings were in line with what teachers experienced in the Turner, Dominguez, Empson, and Maldonado (2013) study, where revoicing and gesture became crucial to the expression of the mathematical ideas in the language of the students. The mentor students did express an increase in comfort in using Spanish for mathematic through the experience of the intervention and, in the case of Leticia, felt more confident in their abilities to continue this trend in the future, saying, "Now I feel like I would be a better tutor if I had to translate too. Now I know

how to do it." This experience in the mentor-mentee relationship affected one mentor not just in the intervention but, as was the case with Carlos, the intervention holds something for him in terms of future career goals.

Poverty

During the pre-intervention focus group interview, Eduardo discussed how his parents had left the Dominican Republic for opportunity in the United States, where he has been both born and raised. Eduardo made many comments regarding the influence of his family's socioeconomic status on how he has approached education over the years but, additionally, during the intervention he and Ricardo had spoken in a sidebar about how, from both of their families, there was tremendous pressure to go into one of three fields perceived as financially lucrative: medicine, law, and engineering. Eduardo had mentioned he didn't know what he wanted to major in next year, while Ricardo was grappling with his own desires to think about majoring in criminal justice instead of forensics. During the post-intervention interview, though, Eduardo stated he had come to a current decision about his future.

> It was a learning experience not just for the people we were mentoring but for us too. This made me realize what I really want to do, like, I want to be a teacher. Maybe not a math teacher (laughs). English is probably what I'm leaning towards. But I loved this, and I'm telling my family I'm going to be a teacher.

While many students change majors and career paths throughout their collegiate years, at this time, Eduardo is expressing the impact that the *AfterMath Intervention* experience had on him personally, to the point where his major choice is not being as influenced by the potential monetary gains.

Student Mathematical Learning

Through their participation in *The AfterMath Intervention*, the mentors resoundingly reported feelings of increased confidence in their own mathematical skills.

Paola: It was very much a learning experience in the way we got to bounce ideas off of one another and talk about the answers that we got. I improved a bit in math and my understanding of statistics because of this.

Leticia: It was like a refresh of things that we already knew. Because when I signed up [to participate] at first I was kind of worried that I was not so good, but then it got easier.

Andres: Yeah, the qualifications listed seemed scarier at first. But I really do understand probability now!

The mentors all reported that their current mathematics class are going well, and they feel stronger having had the mentoring experiences. When asked if they would participate in a program like this again, the agreement was resounding, with many already looking to tutoring jobs as student employment options.

In terms of learning and the experience as a whole, both mathematically and environmentally, Eduardo and Angel summed the group feelings succinctly:

Eduardo: This created a lasting friendship between all of us. Even the people I didn't work with, being around them now, we are just linked so much because this dissertation study gave us a little group where we could bounce things off each other.

Angel: It gave us a common experience to unite around.

Summary of Mentor Post-Intervention Focus Group Interview

The cohort of the seven mentors reported feelings a positive experience in being a part of the intervention. They collectively feel stronger about their own skills in probability specifically

and mathematics in general, and they also have grown in bilingual academic skills in terms of communication of mathematical ideas. Several of the mentors are now serving as tutors or are in training to do so, and they feel more confident in their skill sets. One mentor is considering a career in education now due to his participation in the *Probability in the AfterMath*, and all expressed assent to the feeling of being united by the intervention as a group of not just mentors and mentees, but students with a shared experience.

Summary

The mentees in the *Probability in the AfterMath* intervention saw statistically significant gains in probability concept knowledge from the time of pre-intervention to post-intervention. When looking at specific Common Core State Standards separately, the most significant gains were made in the conceptualization and execution of the multiplication rule for compound probabilities. The study mentees reported feeling more confident in their probability understanding and language skills after the intervention, while also expressing that they were more likely to seek help and ask questions in class than before. The mentors likewise conveyed sentiments of increased confidence in their ability to perform and assist in mathematical tasks and to do so in English and Spanish. Though many mentees still feel a sense of displacement in their new setting, both the mentees and mentors agree that a lasting cohort of friendship and connection has been made through their participation.

CHAPTER FIVE: SUMMARY, DISCUSSION, AND RECOMMENDATIONS

Introduction

In this chapter, the findings from the study are summarized and discussed in the context of the *AfterMath Theoretical Framework* categories of language, poverty, neocolonialism, student mathematical learning, and natural disaster interruption. Both qualitative and quantitative results are connected and compared to the findings of previous research documented in the literature review, and implications of the findings are discussed. The limitations of this brief but intensive intervention are analyzed with recommendations for future research. Finally, possible extensions of this study are posited in the context of the very natural disaster that interrupted this study about education post-natural disaster interruption.

Summary and Discussion of Findings

In this section, the *AfterMath Theoretical Framework*, shown in Figure 33 on the following page, is again used as a lens through which to view the factors influencing the students through the course of the study. Language, poverty, and neocolonialism all impacted student mathematical learning in meaningful ways. Finally, the overarching theme of natural disaster interruption is discussed in the context of the study findings.

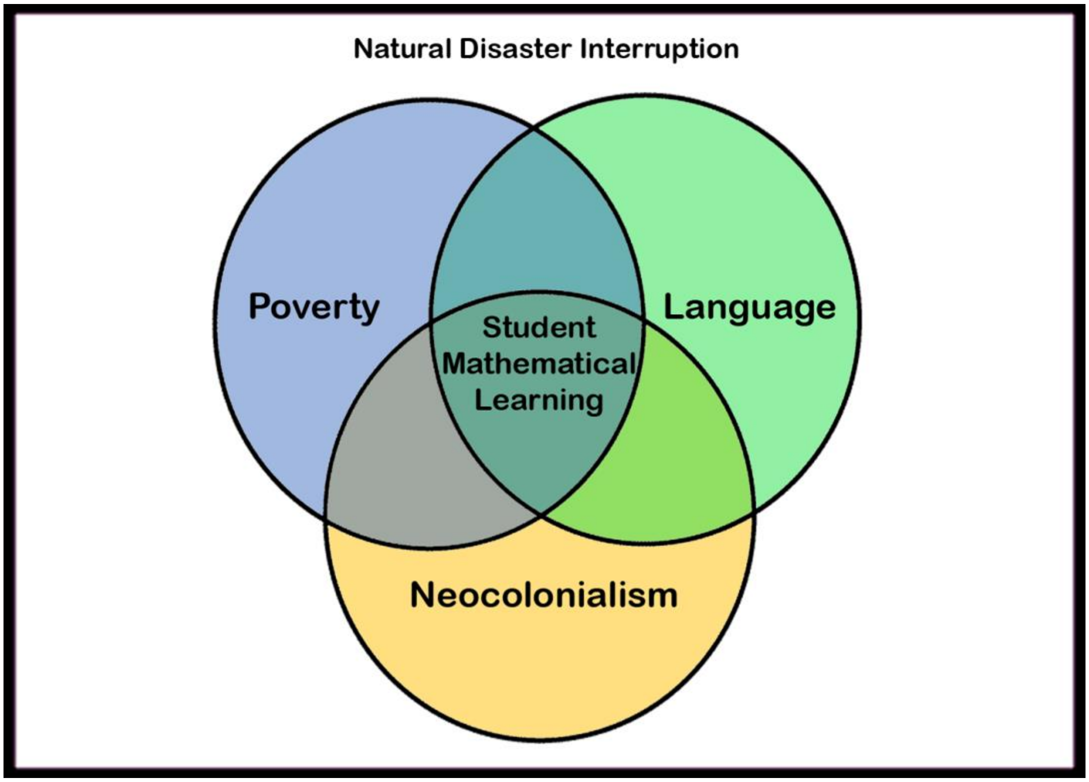


Figure 33: AfterMath Intersectionality Framework

Language

During the course of the study, language played a prominent role both as a unifier among the mentors and mentees as well as a stumbling block within the mathematical learning itself. Although the students were hesitant at first to speak and write in Spanish at the onset of the study, casual conversations regarding the material and its relevance to them became a forum for the students to own their language and culture. As an illustrative example, Genesis and Paola laughed during Task 1, *Home Away From Home,* regarding how, when Genesis moved from Puerto Rico, she was excited that the city in which she now lives has a Spanish name but quickly became disappointed when people “said it wrong here,” and now she felt the need to “say it wrong, too.” While this conversation may seem basic at first, this paved the way for multiple

students to share linguistic experiences, and a shift of language and comfort was seen as they began to dig deeper into designing their sample space.

Over the course of the next two tasks, a notable linguistic shift was made to expression in Spanish, with many of the mentor and mentee pairs communicating verbally in Spanish. Additionally, as was seen in Jesus' illustrative example in the results, results and reflections were written in Spanish in certain cases. This shift to native tongue seen by the students aligns with what McCormick (2016) and Willans (2017) discussed as an educational unifier and a step away from previous classroom experiences. In contrast to the findings of Llabre and Cuevas (1983), the students here navigated terms with lexical ambiguity as laid out by Kaplan, Fisher, and Rogness (2009) with great skill in Spanish and came out with a high level of performance on the tasks.

When it came to the final two tasks, using the United States Census Bureau data, the shift to English came back almost as immediately as it had left in the second and third tasks. While in the first three tasks the students themselves had been the creators of the sample spaces and data sets, here they came in contact with a previously existing data set for the first time. Although the students in the fifth task, *Mi Familia in the Future*, were asked to reflect upon where they saw themselves within the data, all mentees chose to shift their written expressions back to English. Chernoff and Zazkis (2011) made the argument that the creation of sample space was a best practice in student understanding. What was interestingly seen here is the students maintained a high-performance level after culturally and linguistically relevant sample space creation, even when shifting to a formally produced data set where they felt more comfortable interacting in English.

Poverty

The student experiences with poverty came in more subtle ways during the *AfterMath* intervention. While there was general discussion of gaps in mathematical knowledge both during the pre-intervention interview phase as well as between the mentees and their mentors while participating in the tasks, one of the ways in which poverty came to light the most was in terms of the mentee students' sharing of their educational backgrounds. The majority of the mentees came from private school backgrounds, but as Genesis, for example, was quick to point out, this was often as a perceived necessity to have a present teacher rather than a commentary on a socioeconomic advantage. Indeed, Carlos discussed at length in pre-intervention focus group interview the changes he saw in his private school, which was still slow to rebuild. Carlos' experience is not unlike the shifts seen in the schools in New Orleans post-Hurricane Katrina, when a systematic overhaul went into effect (Perry, 2006). Vallas (2014) discussed a similar trend of popularity of private schooling in the Caribbean island nation of Haiti after earthquake devastation, but here the mentee students indicated that private schooling had been an ongoing trend to combat the issues of poverty found in the government-run schools.

The subject of poverty presented again strongly in the post-intervention focus group interview of the mentees, where Carlos, Jose, and Jesus expressed a desire to return home but faced resistance from their families in doing so due to the socioeconomic conditions in Puerto Rico in contrast to Florida. As natural disasters disproportionately affect areas of high poverty the longest (USAID, 2014), the students' establishment of a new home and schooling experience is indeed rooted in the situation of systemic poverty found in Puerto Rico. However, even through this, the trio found solace in each other, with Carlos and Jesus especially forming a strong bond after having met through the intervention. Prior to this, Jesus and Jose were the only

natural disaster displaced students in the cohort aware of each other's existence. Though the students may be experiencing permanent relocation due to economic reasons, they are at the very least united in their quest to continue their schooling.

Neocolonialism

Among the mentee students, there were many assumptions regarding the school and school culture that the connection with the mentors helped to change. In the pre-intervention interviews, several mentees discussed a previous schooling situation where the classroom culture was of a nature where they did not feel comfortable speaking out or asking questions, especially if a mathematical topic was not understood. However, through the connections with the mentors, the mentees began to experience a shift in their classroom behavior outside of the study.

Luis, after interacting with Angel, began to seek help with his mathematics through free services offered by the school of which he was previously unaware. In contrast to the experience he described in Puerto Rico, he began to interact with teachers and actively seek help. This connection, which came straight from the "buddy system" emphasized as a best practice for SIFE's (Spaulding, Carolino, & Amen, 2004), was key in connecting Luis to the proper resources so that he could begin his integration into the school culture and feel comfortable enough to take advantage of resources available. Similarly, Jesus reported that, as the intervention went on, he began to feel more comfortable speaking up and asking questions in class than he had previously. These experiences of adaptation to a more constructivist classroom were seen as a direct consequence of the active environment in which the students found themselves in the study. This parallels the findings of multiple studies regarding active bilingual classroom environments where code switching is allowed and encouraged (e.g., Phakeng & Moschkovich, 2013; Setati, 2015; Turner, Dominguez, Maldonado, & Empson, 2013). During

the tasks, there was often banter of this “not feeling like a normal math class,” and the students were challenged to begin dialogue and rely on interaction in order to complete the tasks at hand. The design of the tasks, which initiated raw data collection that mandated the involvement of all mentors and mentees, created an environment where students realized they would not be the passive receivers of mathematical knowledge. The fact that this has carried over into their traditional classroom setting by their own report is a potentially lasting consequence of the intervention experience.

Student Mathematical Learning

The mentee students involved in the study came in with an incomplete knowledge base of probability concepts. Though the majority of the students were in Algebra II and, according to the Puerto Rico Core Standards (2014), should have a base knowledge of simple and compound probabilities, this was not seen in the pre-test results, where students scored a low mean on the seven-point grading scale ($M = 1.75, SD = 0.80$). As all students who were administered the pre-test had been affected directly by Hurricane Maria, this does align with the findings of Lamb, Gross, and Lewis (2013) regarding student mathematical performance post-natural disaster interruption. However, this impact hypothesis should still be viewed with caution. As the aforementioned spheres of the *AfterMath Intersectionality Framework* have demonstrated, there are mitigating factors in the student experience beyond the disaster, though not isolated from it. The students’ mathematical learning has certainly been affected by issues of language, poverty, and neocolonialism, alongside the significant natural disaster interruption experienced with the onset of Hurricane Maria.

Through the tasks, the students made significant gains in their understanding of probability and ability to perform proper calculations involving sample space, compound

probabilities, and conditional probabilities. By being actively involved in creation of sample spaces and collecting data that was meaningful to them, the students took ownership over their own learning in a way that aligns with best practices indicated by previous research in probability (e.g., Chernoff & Zazkis, 2011). Students made gains in both sample space and conditional probabilities, the two topics in probability most emphasized in *Catalyzing Change* as barriers to further understanding in more complex statistical topics (NCTM, 2018). By using the approaches to learning conditional and compound probabilities through a focus on independence instead of combinatorics as recommended by Moore (1990), the students were able to switch successfully from developing their skills in a culturally responsive, translingual environment to successfully performing calculations and reflective analysis from previously existing datasets, filled with information not pertaining to the question at hand. Indeed, by the end of the intervention, the students showed statistically significant gains in probability on the post-test when compared to the pre-test and reported feelings of increased confidence and understanding in mathematics. Jose, Hector, and Genesis all repeatedly reported increased understanding and the ability to use their knowledge in their own classrooms. Hector, in particular, made significant gains in understanding, calculation skills, and the ability to verbalize his thought processes.

The mentees were not alone in their feelings of increased knowledge of probability, however. The mentors additionally reported more confidence in their own mathematical skillset, with some having enough validation by the intervention to decide to become tutors and continue to use their combination of bilingual skills and mathematical knowledge to aid students in a formal environment. This highlights the views of Ocasio (2009) on the important asset of bilingualism and the effects of student efficacy when they view their linguistic differences as a

strength and not a gap (2009). Here, this comes into play for the mentors in the very distinctive purpose of aiding peers in mathematical achievement.

Natural Disaster Interruption

The overarching theme of natural disaster interruption came as a backdrop to the student experience in the *AfterMath* intervention. The hurricane itself as an event was rarely discussed. Rather, the context of the disaster would be talked about among students in terms of how things were changing (or not changing) “back home.” For the students whose entire family had moved and been displaced as a unit, this interaction with the natural disaster experience often took the shape of communication with friends and extended family members. However, for Carlos, who moved to live with different family due to the natural disaster, the interruption played a much more meaningful part in his academics and mathematics in particular.

Carlos’ goal to enter the military and, specifically, the United States Coast Guard is directly due to his desire to assist those in his native home the next time a hurricane or tropical storm comes to the island. For Carlos, the intervention was not as much about strengthening his mathematics skills for his future classroom experiences. Rather, Carlos has already set his mind to preparing for the ASVAB test and is readily aware of the scores and skills needed in order to perform well enough to have the option to be in a position where he feels he can be the most helpful. Carlos admitted several times during the study that he is not a “people person,” and he views the Coast Guard as his pathway to aid people in a way in which he is comfortable. Even with not being overly sociable, Carlos still formed a strong bond with Jesus over the intervention and also regularly interacts with his mentor Andres in the school setting. Indeed, this establishment of a newcomer cohort, backed by the research of Seilstad (2018) and Suarez-Orosco, Pimentel, and Martin (2009) has been found to be essential in the support and sense of

belonging felt by immigrant adolescents. Though it is impossible to know what the future will hold for Carlos and the other mentees, it is hoped that the bonds and knowledge formed through the intervention will in some small way aid them in their goals.

Implications

Through this study, the mentees saw statistically significant results in terms of probability skill and reported general feelings of increased confidence and understanding that were upheld in their written work and post-task reflections. The study confirms the idea previously seen in research like that conducted by Gerena and Keiler (2012) that short, intensive, bilingual interventions in mathematics education can have meaningful impacts both quantitatively and qualitatively. Unique to the aforementioned research, however, is the one-on-one pairing with the native speaking mentors to complete the culturally responsive tasks. Through these tasks, not only did the mentees see improvements in their understanding, but the mentors reported increased levels of confidence in their own reasoning in probability and the ability to switch between languages when explaining academic items. Furthermore, this establishment of a newcomer cohort saw a uniting of the students in the study, supporting the research of Dover and Rodríguez-Valls (2018) and Seilstad (2018).

For students who have had their education plagued by a natural disaster interruption, the implications of this study are meaningful. The research of Felices Sanchez (2013) and Marchetta, Sahn, and Tiberti (2018) warned of dropout rate increasing and mathematical competency decline in areas plagued by natural disaster interruption. However, with this intensive intervention serving as a way to aid those affected students in their mathematical skills while providing a place of belonging, there is potential for these impacts to be softened. Spencer, Polachek, and Strobl (2016) hypothesized that negative differences seen in mathematics

achievement after hurricane interruption were due to the lack of availability of home guidance in assisting with the subject matter. By using the unique mentor model at the students' school of instruction, this eliminated the barrier cited by these researchers.

Although the overarching theme of this study was to aid those whose education had been interrupted by natural disaster, the culturally responsive tasks, language transition, and use of the one-on-one mentor model are practices that can transcend beyond those affected by natural disasters to students identifying with various constructs of the *AfterMath Intersectionality Framework.* For students trying to find themselves within mathematics and make meaningful connections, having culturally responsive tasks is key to sensemaking. Though in this study two languages were used between the mentees and mentors – English and Spanish – a multilingual classroom could still benefit from this model. If there was no mentor available who shared a native tongue with a new mentee, a connection could still be made through a cultural commonalities or shared experiences, including being a newcomer due to any number of circumstances. The key implications from this study, above all, are the need for students to make connections in order to have the best opportunities for success, and these connections take the form of finding oneself in the mathematics material at hand, in the institution of learning, and in their peer group.

Implications for Practice

For teachers who find students in their classrooms who have been affected by an interruption in their formal education, the assignment of a one-on-one mentor was seen as an essential way to connect the mentee student with both the material and the school at large. This supports the findings of previous studies on one-on-one peer interaction in the K-12 school setting, especially with students with linguistic differences (e.g., Gerena & Keiler, 2012; Peercy,

Martin-Beltrán, Silverman, & Nunn, 2015; Spaulding, Carolino, & Amen, 2004). For teachers who additionally may not share the culture or language of the newly arrived displaced student, this pairing becomes even more meaningful as a supportive connection within the classroom, as was previously seen in the research of Demski (2009). Furthermore, the encouragement of a multilingual environment upholds the view of linguistic differences as a point of advantage rather than a deficit, and this is itself is of utmost importance in creating a learning environment in which students feel uplifted and a sense of belonging rather than an outsider who is viewed as being behind.

In the mathematics classroom in particular, the practice of involving the students in their own data collection in order to allow them to communicate and become an integrated part of their learning was seen as an effective technique. With this initial push for investigation and interaction, the students were able to quickly move pass a passive learning environment and take responsibility for their learning in a friendly, comfortable environment. Additionally, having culturally relevant tasks which the students could discuss that brought in their own backgrounds and interests allowed the data collection to be more meaningful. This by-in from the students early on has been supported through studies by Dachyshyn & Kirova (2011) and Higinio Dominguez, López Leiva, and Licón Khisty (2014), among others, to create an inclusive learning environment, especially in mathematics. Thus, the unique marriage of one-on-one peer mentoring and active, culturally responsive tasks can be transcended beyond an intensive intervention such as the one described in this study and into integrative everyday classroom practice. Though these tasks were designed for a Puerto Rican cultural context, the culturally responsive tasks could be adapted to be appropriate for any culture, as the goal is for the students

to be able to see *themselves* in the mathematics. Furthermore, though these were created to be used in the context of probability, culturally responsive tasks can be used across the fields of mathematics for students to make meaningful connections.

Limitations

This small, intensive intervention had several limitations. First, the study occurred at a single high school in Florida with a sample of six mentees and seven mentors. The school in which the study took place, though a public high school, was also a magnet school of choice. Though the school has no academic minimum scores for admission, there is a requirement for students to maintain a 2.0 grade point average in order to remain at the school. This alone makes the pool from which the students were selected different from a typical zoned public high school. As Pane, McCaffrey, Kalra, and Zhou (2008) have found that the performance of students post-interruption is far less if they are enrolled at a school that is higher performing than the one from which they came, this possible impact cannot be ignored. Thus, the results found here may not be representative of other schools, and further research should be conducted with other sampling locations.

Due to the small size of the school and the fact that students opted in to participate in the study, there were some common characteristics among the participants. The school that served as the study site did have in its population more students who had been displaced by Hurricane Maria. However, at least one potential participant declined not due to the mathematics but to concerns of psychological effects of being in a group who all shared the experience of natural disaster devastation. This brings to light the need for sensitivity and support when working with students who have undergone a traumatic experience and, as counseling services were not in the scope of this study, this was indeed a limitation.

Finally, the *AfterMath* study took place as a short, intensive intervention with a pre-test and post-test at the beginning and close of a six-week time period. In order to make more broad-based determinations about long-term gains in mathematics, longitudinal analysis should be conducted to follow the mentees through their academic pursuits. Then more confidence may be given to the results and their significance and impact.

Recommendations for Future Research

There are many potential avenues for future research stemming from this study. As previously mentioned, the fact that the *AfterMath* intervention was a short-term initial study. This study did have statistically significant results in terms of student performance, and this is not isolated with short-term intervention studies of this nature (e.g., Gerena & Keiler, 2012). However, longitudinal analysis that would track the progress of the mentees over the years in their mathematical performance and attainment would be an interesting place to start. Additionally, in the post-intervention interview, Carlos, Jose, and Jesus all expressed a desire to return to Puerto Rico to finish their schooling. At this time, none of the three felt this was likely to occur. However, in the case that any one of the mentees did return to Puerto Rico, doing a comparative post-intervention study of those who returned as compared to those who stayed in Florida to analyze items such as mathematical achievement and educational attainment could prove interesting. Additionally, the comparison of any mentees who returned to Puerto Rico to peers who persisted in their schooling on the island post-Hurricane Maria could also possibly show intriguing results on the impact of temporary formal schooling in times of interruption.

In addition to the aforementioned need for longitudinal data analysis, future research can take place in the form of the continuation of the project as previous mentees who have “graduated” from the *AfterMath* program, so to speak, become mentors to new students who

have come into the school after natural disaster displacement. During the time in which the intervention in this study took place, the Caribbean was once again shook by a catastrophic storm. Hurricane Dorian became the most devastating natural disaster to hit the Bahamas, causing, as of October 2019, seven billion dollars in damage, a death toll of 60, and 424 still unaccounted for (Russell, 2019). Educationally speaking, 10,000 students have been declared as displaced, and the Bahamian government alongside UNICEF has been working to establish emergency schooling opportunities for the affected students (Fagenson, 2019). Although the United States government did not elect to grant temporary protection status to Bahamians displaced by Hurricane Dorian, many have started to arrive to connect with family and educational opportunities in the country (Bechara, 2019; Hampton University, 2019). With this, the cycle of natural disaster displacement continues, and there is immense potential for future study with the next group arriving under similar circumstances.

The tasks and study at hand focused on probability specifically, but future research on other types of mathematical problems with intensive vocabulary could yield interesting results. There is potential for research to expand to algebraic and geometric fields and for the inclusion of modeling tasks into the interventions. While probability was the focus here, higher level statistical concepts could also be tested in the future, with a second phase touching on topics of normal curves and statistical inference. Due to the small pool from which the mentees for this particular study were drawn, there was a great deal of variation in some important characteristics of the students. First of all, the mentees had varying levels of mathematics courses in which they were currently enrolled. Although the majority were in Algebra II at the time of the study, one mentee (Hector) was in Geometry and another (Luis) was in Algebra I. Though much of the

variation in background knowledge was mitigated by the fact that the results measured student growth as opposed to mastery, this variation could be a pathway for future research.

In addition to the differences in students' mathematical backgrounds and enrollment, there were also ranges of English language proficiency among the mentees. Therefore, strategies used with the mentees may not apply to students across all language proficiency designations. More study on the approaches used in this intervention but focused on students with more consistent language proficiency, especially in the beginning levels, could prove noteworthy. On the opposite side of the variation, this study only consisted of one of the female mentee (Genesis). Though Genesis did not perform differently in terms of gains in probability content knowledge than the males in the study, she did drive much of the conversation covered by the qualitative portion of the analysis. Therefore, future research that focuses on gender in mathematical achievement post-educational interruption could be a useful branch off this study.

Finally, these tasks were designed with a Spanish-speaking Puerto Rican population in mind. These tasks were culturally responsive to that population but can be modified to be culturally responsive for other groups of displaced persons. Both the pre-test/post-test instrument and the collection of tasks are easily adaptable to other languages and cultural contexts and can serve as a framework for future study. Additionally, the *AfterMath Theoretical Framework* that guided this study looked to the intersections of language, poverty, and neocolonialism that had influenced the students' mathematical learning. This framework could be used directly or adapted for future study when looking at the complex identity of those who have had their educations interrupted. The hope is that this intervention may even transcend the field of natural disaster interruptions and be able to be used in future research in multiple forms of educational

interruptions, whether it be political refugees or situations of chronic or severe illness. By using a culturally responsive intervention where one-on-one mentoring led to rich interactions and a supportive cohort environment, collaborative learning can take place in a variety of contexts of returning from time away from formal education. No matter the context, though, the hope is that this research will provide a launching point for others who are interested in equity and access in mathematics education in the aftermath of an interruption.

Summary

In conclusion, this study provided a launching point both for the individual students involved as well as for future research in mathematics education in the wake of natural disaster interruption. This unique case of equity and access is often overlooked, yet natural disaster interruptions affect millions annually with the numbers growing. For students affected, there must be a way for their education to continue in a way that is meaningful, timely, and culturally relevant. By performing a one-on-one peer mentor bilingual intervention in probability skills, students who had been affected by Hurricane Maria and have had their mathematical learning heavily influenced by factors of language differences, poverty, and neocolonialism saw statistically significant gains in probability knowledge attainment. Furthermore, students reported feelings of increased confidence in their understanding, a new sense of belonging in their school, and more comfortable in asking for help and engaging in their traditional classroom environments. Though this was one brief study with a limited sample, it is hoped that this will provide a launching point for future research on the topic. Students with interruption in formal education due to natural disasters will continue to be subject to displacement. As educators and researchers, it is our duty to see that these students have every opportunity for success in academics – especially in mathematics – in the aftermath.

APPENDIX A: PERMISSION TO USE COPYRIGHT IMAGE

Nicole Flatow [redacted]
Sun 10/6/2019 10:38 PM
Hi Brianna,

You have our permission - thanks for checking and good luck with the paper.

Nicole

Luis Melgar [redacted]
Fri 10/4/2019 11:44 AM

Good morning Brianna,

Sure, feel free to use that map. Although I will suggest you to contact CityLab's editor to double check that they're ok with that – Nicole Flatow [redacted]

You can obtain the image directly from the website. If you want a larger image of the map of Central Florida, I could see if I have the original file in my personal computer (I'm working now in a different news organization).

As you know, the data was provided by Teralytics, so you'll need to source them.

Luis

From: Brianna Kurtz [redacted]
Date: Thursday, October 3, 2019 at 1:42 PM
To: Luis Melgar [redacted]
Subject: Permission to use a figure in a dissertation

Dear Mr. Melgar,

I hope this e-mail finds you well! I am looking to obtain permission from you to use a figure you created in a dissertation for the University of Central Florida about students affected by Hurricane Maria who now live in Florida. The figure is the map of Central Florida with the corresponding highlighted counties and counts of immigration in the article at the link below:
https://www.citylab.com/environment/2018/05/watch-puerto-ricos-hurricane-migration-via-mobile-phone-data/559889/
If I may use this, I just need a statement of permission from you and, if possible, the image file for insertion into the dissertation. Please let me know any questions you may have. I can be reached at [redacted].

Thanks,
Brianna Kurtz
Doctoral Candidate, College of Community Innovation and Education
University of Central Florida

APPENDIX B: INSTITUTIONAL REVIEW BOARD FORMS

UCF IRB Approval Letter

UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

APPROVAL

June 5, 2019

Dear Brianna Kurtz:

On 6/5/2019, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title:	The AfterMath: A Culturally Responsive Mathematical Intervention to Aid Students Affected by Natural Disasters
Investigator:	Brianna Kurtz
IRB ID:	STUDY00000456
Funding:	None
Grant ID:	None
IND, IDE, or HDE:	None
Documents Reviewed:	• Kurtz IRB Approval [redacted] Category: Letters of Support; • Kurtz Faculty Advisor Review, Category: Faculty Research Approval; • Kurtz AfterMath Consent, Category: Consent Form; • Kurtz AfterMath Protocol, Category: IRB Protocol; • Kurtz Interview Protocol Questions, Category: Test Instruments; • Kurtz Pre- and Post-Tests, Category: Test Instruments; • Kurtz Tasks for UCF IRB, Category: Test Instruments; • Principal Support Letter, Category: Letters of Support;

The IRB approved the protocol on 6/5/2019.

In conducting this protocol, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Racine Jacques, Ph.D.
Designated Reviewer

Study Site School District IRB Approval Letter

[redacted]

[redacted]

April 23, 2019

Ms. Brianna Kurtz
[redacted]

Dear Ms. Kurtz,

I am in receipt of the proposal and supplemental information that you submitted for permission to conduct research in the Seminole County Public Schools. Thank you for adjusting your study components to remove impact to students and teachers' instructional time.

You are granted permission to conduct the study described herein, *The Aftermath: A Culturally Responsive Mathematical Intervention to aid Students Affected by Natural Disasters,* at [redacted], pending submission to this office of the UCF IRB approval document.

Your first order of business is to confirm that [redacted] agrees that your study may be conducted on his campus. Please note: I have included Ms. Minnie Cardona in this communication. Ms. Cardona is the SCPS Director of ESOL, World Languages and Student Access. She has personally supported many students and families from Puerto Rico who were impacted by the most recent hurricane. Ms. Cardona and I would appreciate you sharing a copy of your results with this office.

Best of luck!

Respectfully,
Anna-Marie Cote

Anna-Marie Cote, Ed.D.
Deputy Superintendent, Instructional Excellence and Equity

cc. Ms. Mike Gaudreau, Executive Director, High Schools
[redacted], Principal, [redacted]
Ms. Minnie Cardona, Director, ESOL, World Languages and Student Access

"A" Rated Academically High-Performing School District

[redacted]

<u>Study Site Principal Support Letter</u>

[redacted]

April 28, 2019

Institutional Review Board
University of Central Florida
UCF Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, FL 32826

UCF IRB Team:

It gives me great pleasure to write this letter of permission for Ms. Brianna Kurtz to continue her doctoral research in partnership with [redacted] and [redacted] Public Schools.

Ms. Kurtz exemplifies professionalism through her instruction and interaction with students and teachers. She is a valued member of the [redacted] faculty and the [redacted] community. It is without hesitation that I grant permission for Ms. Kurtz to continue her doctoral research with our students and faculty at [redacted].

Sincerely,

Brandon M. Hanshaw

Brandon Hanshaw, Ed. D.
Principal
[redacted]

[redacted]

“[redacted] is a member of the NAF/National Academy Foundation”

Informed Consent Form

UNIVERSITY OF CENTRAL FLORIDA

Title of research study: *The Aftermath: A Culturally Responsive Mathematical Intervention to aid Students Affected by Natural Disasters*

Investigator: *Brianna Kurtz, M.S.*

How to Return this Consent Form: You are provided with two copies of this consent form. If you give consent for your child to participate in the research, please sign one copy and return it to the teacher, Brianna Kurtz, and keep the other copy for your records.

Key Information: The following is a short summary of this study to help you decide whether or not to be a part of this study. More detailed information is listed later on in this form.

Why is my child being invited to take part in a research study?

Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. The observer, Ms. Brianna Kurtz, will be running a six-week intervention three to four days each week during which approximately seven junior and senior level students who have Spanish language knowledge and have successfully completed or are currently enrolled in Dual Enrollment Statistical Methods I or Advanced Placement (AP) Statistics at the [redacted] will be working as mentors and tutors to underclassmen students, also enrolled at the [redacted], who have arrived in Florida schools in the past 18 months due to displacement by the effects of Hurricane Maria. Your child has been identified as fitting into one of these categories.

Why is this research being done?

The purpose of this research study is to provide a brief and intensive intervention to the students who have entered the mathematics classrooms of a Florida high school by treating them as a newcomer program cohort where they will be paired with same-language mentors to help in achieving a greater understanding of topics involving probability.

How long will the research las t and what will my child need to do?

We expect that your child will be in this research study for 3 lunch periods each week for approximately seven weeks, up through September 30th, 2019 at the latest.

Your child will be asked to participate in two group interviews about their experience in mathematics. Each interview will be no more than 45 minutes in length. Then, students will complete a pre-test of skills, again approximately 45 minutes in length, work on no more than eight tasks in 30 minute settings about probability with a peer mentor, and complete a post-test and group final interview, each no more than 45 minutes in length.

More detailed information about the study procedures can be found under ***"What happens if I say yes, I want my child to be in this research?"***

Is there any way being in this study could be bad for my child?
The risks to participation are minimal and do not exceed the risks associated with activities found in daily life.

Will being in this study help my child any way?
The goal of this study is to increase levels of mathematical understanding and skill in students. The main benefit that is hoped to be gained from this study is in mathematical gains. Additionally, for the students from Puerto Rico, it is hoped that this cohort will provide a positive peer group as they adjust to life in a new schooling environment.

What happens if I do not want my child to be in this research?
Participation in research is completely voluntary. You can decide to have your child participate or not to participate.

Your alternative to participating in this research study is to not participate.

<u>Detailed Information:</u> The following is more detailed information about this study in addition to the information listed above.

What should I know about a research study?

- Someone will explain this research study to you and your child.
- Whether or not you allow your child to take part is up to you.
- You can choose not to allow your child to take part.
- You can agree to allow your child to take part and later change your mind.
- Your decision will not be held against you or your child.
- You can ask all the questions you want before you decide.

Who can I talk to?
If you have questions, concerns, or complaints, or think the research has hurt your child, talk to the research team: Brianna Kurtz, Doctoral Student, Mathematics Education, College of Community Innovation and Education, [redacted] or Dr. Erhan Selcuk Haciomeroglu, Faculty Supervisor, at [redacted].

This research has been reviewed and approved by an Institutional Review Board ("IRB"). You may talk to them at 407-823-2901or irb@ucf.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your child's rights as a research subject.
- You want to get information or provide input about this research.

How many people will be studied?

We expect 10 - 14 people will be in this research study.

What happens if I say yes, I want my child to be in this research?

Your child will either serve as a mentor or mentee during the course of the study and work on probability skills through a series of culturally responsive, dual-language problems in order to help gain knowledge of the mathematical content.

If your child is selected as a mentor, he or she will participate in a 45-minute group interview about their experiences in mathematics both pre-intervention and post-intervention. They will also participate in an approximately 45-minute training and refresher about probability skills. Following the pre-intervention interview and training, the intervention will begin. During the course of six weeks, they will meet with their mentees three times per week for three weeks during 30-minute lunches in Ms. Kurtz's room, [redacted], at the [redacted] to work on eight probability tasks.

If your child is selected as a mentee, he or she will participate in a 45-minute group interview about their experiences in mathematics both pre-intervention and post-intervention. They will also participate in a pre-test and post-test to assess knowledge and gains made in probability, both approximately 45-minute training and refresher about probability skills. Following the pre-intervention interview and pre-test, the intervention will begin. During the course of six weeks, they will meet with their peer mentors three times per week for three weeks during 30-minute lunches in Ms. Kurtz's room, [redacted], at the [redacted] to work on eight probability tasks.

Your child will be audio for recorded during this study. If you do not want your child to be recorded, he or she will be able to be in the study. Discuss this with the researcher or a research team member. If your child is recorded as part of this study, the recording will be kept in a locked, secure place. The recording will be erased and destroyed following data analysis and no later than November 18, 2019. Anecdotal field notes will also be taken, and student work will be collected. All data will be stored on a secure server for five years time, after which it will be destroyed. For the purposes of the study, your child will be given a pseudonym and will never be identified by his or her true name nor will the [redacted].

Only basic information from the [redacted] will be used in the study in order to aid in initial student recruitment. This information includes grade level, schooling history, course history, and academic performance. This gathered information is for recruitment purposes only and will not be published or indicated in the study itself.

What happens if I say yes, but I change my mind later?

You can choose to have your child leave the research at any time it will not be held against you or your child. Your child's grades, enrollment, status, or any relationships will not be affected by a change in participation in this study.

If you decide to leave the research, contact the investigator so that the investigator can be aware of your child's stopping participation.

What happens to the information collected for the research?

Efforts will be made to limit the use and disclosure of your child's personal information, including research study to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of this organization.

Student work and audio recordings will be collected. Hard copies will be stored in a locked cabinet in the teacher's classroom for which she has the key. Digital copies will be encrypted and password protected. All identifiers will be removed after data analysis and no later than November 18, 2019, as will all audio recordings. After 5 years, all collected data will be destroyed. For the research, only pseudonyms will be used for the students, and the school will not be identified.

Signature Block for Children

Your signature documents your permission for the named child to take part in this research.

Printed name of child

Signature of parent or individual legally authorized to consent to the child's general medical care

Date

- ❑ Parent
- ❑ Individual legally authorized to consent to the child's general medical care (See note below)

Printed name of parent or individual legally authorized to consent to the child's general medical care

Note: Investigators are to ensure that individuals who are not parents can demonstrate their legal authority to consent to the child's general medical care. Contact legal counsel if any questions arise.

Signature of parent

Date

Printed name of parent

APPENDIX C: PROBABILITY IN THE AFTERMATH PROTOCOLS, INSTRUMENTS, TASKS, AND RUBRICS

Mentor Protocol

The AfterMath Mentor Protocol

Thank you for agreeing to be a mentor for the AfterMath study! You have been selected to participate in this study due to your high performance and knowledge of mathematics and your bilingual English-Spanish skill.

Over the course of the next six weeks, we will be meeting three times per week in my classroom during lunch according to your calendar. You will be directly paired one-on-one with a mentee who is a student at the high school. The student may be in Algebra I, Geometry, or Algebra II, and all will have arrived from Puerto Rico to live in the United States since Hurricane Maria's landfall in September 2017. Many of these students faced a prolonged interruption to their formal education and thus may have a gap in their skill set. In Puerto Rico, much of school is conducted in Spanish. Now these students find themselves in our mainland United States schools, learning all subjects in English. As you may remember from your previous math classes, most of the problems in your probability units were word problems, and most certainly delivered in English. Your job during the classroom sessions will be to work alongside your mentee on probability problems with your choice of language.

You may speak and read with your mentee and with each other in English, Spanish, or any combination thereof. If your mentee is stuck on a particular word or term, please feel free to use your Spanish to help explain the terminology. Again, you were chosen for your bilingual skills. Do not shy away from using them!

You were also chosen due to your mathematical strength, but also, you do not need to be the expert on every question. This is not a test, so please feel free to consult with each other or me if you have questions about the content. The goal here is for everyone to gain a broader understanding of probability, make gains in English vocabulary, and be better prepared for the mathematics classroom here at the school. There is never shame in asking for help. That being said, also please stay focused on the task at hand as much as possible during the sessions. I do want you all to get to know your mentees and to build a bond in the cohort, but we need to make sure the mathematics is done, too!

You are expected to come to every session and to be on time and present until the session has ended. If an emergency arises and you will not be able to attend a session, please let me know as soon as possible so that I may make arrangements. This study relies on your active and continued participation from today, August 16, 2019, until the last session of report for you on Thursday, September 26, 2019.

Thank you again for your participation in the study! We will discuss questions and concerns today at this training session.

Ms. Brianna Kurtz
Doctoral Candidate
University of Central Florida

Interview Protocol

Probability in the AfterMath Interview Protocol
1. What has been your overall experience in learning mathematics? 2. What has been your biggest challenge in learning mathematics? 3. When you hear the terms “probability” and “statistics,” what comes to your mind? 4. Do you think of statistics differently than other mathematics? 5. How do you think being Latino/@/x influences your learning in mathematics? In probability and statistics? 6. What do you wish was different about your experience in learning probability and statistics?

Mentee Pre-Test / Post-Test

AfterMath Pre-Test / Post-Test

Researchers have for a long time been interested in the relationship between cigarette smoking and lung cancer. The following table show the percentages of adult males observed in a recent study.

	Smokes	Does not Smoke
Gets Cancer	0.06	0.03
Does not get Cancer	0.15	0.76

1. Suppose an adult male is randomly selected from this population. What is the probability he smokes?

2. Suppose an adult male is randomly selected from this population. What is the probability he smokes and gets cancer?

Use the following contingency table for questions 3 and 4:

A group of 300 children, ages 4, 5, and 6, took a trip to the zoo. Following their trip, the children were asked which animal was their favorite animal, given the choices of lion, alligator, monkey, ostrich, or elephant. The following table lists the results of the children's answers.

	Lion	Alligator	Monkey	Ostrich	Elephant	Total
4-yr old	15	10	25	5	20	75
5-yr old	32	20	48	2	23	125
6-yr old	23	7	40	12	18	100
Total	70	37	113	19	61	300

3. If a child is randomly selected, what is the probability that the child is 4-years old *or* has the ostrich as favorite animal?

4. Find the probability of randomly selecting a 6-year old child, *given that* the child's favorite animal is the elephant.

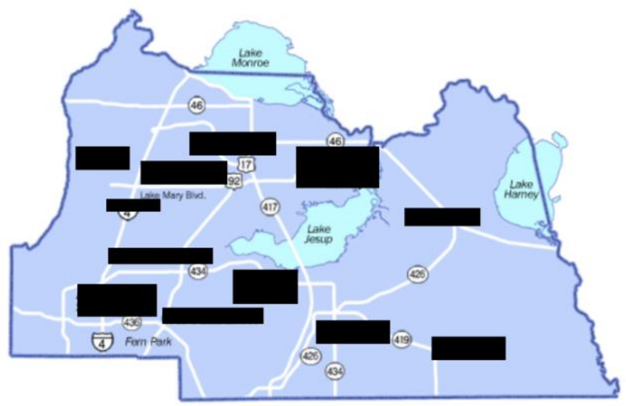
In cleaning out your cupboards, you find an old Halloween candy bag containing 12 assorted candy bars. There are 4 Snickers, 6 Milky Ways, and the rest are Three Musketeers. Suppose three candy bars are selected at random. Answer questions 5-7.

5. What is the probability that all are Snickers (with replacement)?

6. What is the probability that all are Snickers (without replacement)?

7. What is the probability that you select two Milky Ways and one Three Musketeer (without replacement)?

The AfterMath Task 1: Home Away From Home



Where do you come from? On this map of [redacted], please have you and your mentor mark where you currently reside.

1. **Can you and your mentor mark the same location? Why or why not?**
2. **Go to others around the room and add their locations to your map.**
3. **What is your sample space now of locations?**
4. **What would be the probability of selecting someone who lives in [redacted] by chance alone? How would this change if we had not collected the locations from around the room?**

CCSS MATH Standards: 7.SPA.1, 7.SPC.5, HSS.CP.A.2, HSS.CP.A.5

Task 2: Missing the Mofongo

The AfterMath Task 2: Missing the Mofongo

This week, we are going to use the data from the last sessions about location alongside your favorite local restaurants that, in your opinion, have the best Latin food to make a contingency table. A contingency table is a way to display data that may overlap.

			Student Location	
		[redacted]	[redacted]	[redacted]
Restaurant				

1. **What is the probability of randomly selecting a student in this study who lives in [redacted]?**

2. **What is the probability of randomly selecting a student in this study whose favorite is [redacted]?**

Task 3: Missing the Mofongo *and* the Arroz con Gandules

The AfterMath Tasks 3: Missing the Mofongo *and* the Arroz con Gandules

Below is the contingency table created from our group data. On the rows are the restaurants mentioned, and in the columns are the locations where our students are from. The numbers indicate the number of students who have deemed each restaurant as their favorite based on their home location.

			Student Location	
		[redacted]	[redacted]	[redacted]
	[redacted]	**2**	**4**	**1**
Restaurant	[redacted]	**0**	**2**	**0**
	[redacted]	**1**	**1**	**2**

1. **What is the probability of selecting a student in this study who lives in [redacted] or whose favorite is [redacted]?**

2. **What is the probability of selecting a student in this study whose favorite is [redacted] or [redacted]?**

3. **What is the probability of selecting a student in this study whose favorite is [redacted] or lives in [redacted]?**

4. **What is the probability of selecting a student in this study from [redacted] whose favorite is [redacted]?**

5. **What is the probability of selecting a student in this study whose favorite is [redacted], who is from [redacted]?**

6. **What is the probability of selecting two students in this study from [redacted] whose favorite is [redacted]?**

7. **What is the probability of selecting two students in this study whose favorite is [redacted] who are both from [redacted]?**

CCSS MATH Standards: HSS.CP.A.1 HSS.CP.A.4 HSS.CP.A.7 HSS.CP.A.8

Task 4: Mi Familia

The AfterMath Task 4: Mi Familia

Households in the United States come in many different sizes and compositions. Certain studies have shown that there can be a cultural connection with this.

Please go to www.census.gov/prod/cen2010/briefs/c2010br-14.pdf

Here we find information about United States households from the latest U.S. Census, conducted in 2010.

1. **What is the probability that a household has children, given they identify as Hispanic or Latino of any race?**

2. **What is the probability of a household having children under 18, given they live in Florida?**

3. **What is the probability of a household having children under 18, given they live in Puerto Rico?**

CCSS MATH Standards: HSS.CP.A.3 HSS.CP.A.5 HSS.CP.A.6

Taks 5: Mi Familia in the Future

The AfterMath Task 5: Mi Familia in the Future

In Task 4: Mi Familia, you analyzed data from across the country. Now, it is time to reflect on how you and your family fit into these results now and in the future.

1. **How do you identify yourself? What characteristics make up the members of your household? How many people are in your household? Write this information below:**

2. **How do you think ethnicity and location influence household composition? Write a few sentences explaining your reasoning.**

CCSS MATH Standards: HSS.CP.A.3 HSS.CP.A.5 HSS.CP.A.6 HSS.MD.B.7

Mentee Post-Task Reflection Protocol

Probability in the AfterMath Post-Task Reflection Protocol
1. What, if anything, do you feel you understand better after today's task? 2. What do you still feel unsure about related to today's task or have questions about? 3. How would you explain what we did during our session today to a friend who is in Puerto Rico?

AfterMath Task 1 Rubric

Question 1: The intention of the question is to establish an early recognition of independence.	
E	The student answered correctly that they and their mentor either can or cannot mark the same location and justified using city-name geography *or* the student correctly answered that they and their mentor cannot mark the same location as they do not live in the same household.
P	The student answered correctly regarding location but lacked or used incorrect thinking in justification of reasoning.
I	The student incorrectly answered the location marking question.
Question 2: The intention of this direction is to create a sample space.	
E	The student has marked on their map the locations of the other mentors and mentees.
I	The map only shows the original markings from Question 1.
Question 3: The intention of this question is to discuss sample space in context of the collected data.	
E	The student correctly identified the list of city locations OR the households by name of the student as their sample space.
P	The student described the sample space in non-specific terms, such as using the words "all marked cities" or "everyone's house."
I	The student incorrectly identified the sample space.
Question 4: The intention of this question is to recognize the that probability is calculated based on representation within a sample space.	
E	The student correctly calculated both probabilities based on each sample space scenario.
P	The student correctly calculated one of the two probabilities based on each sample space scenario.
I	The student did not correctly calculate either probability.

AfterMath Task 2 Rubric

Contingency Table: **The intention of the question is to properly construct a contingency table from collected data.**	
E	The student correctly entered in values into the contingency table according to the class results.
P	The student used the correct data but mistakenly entered percentages or fractions instead of counts *or* the student made minor entry errors.
I	The student incorrectly entered the values into the contingency table in a way that indicated a lack of understanding of concept over transcription error. For example, a student begins to total the entries and ignores the variables vertically or horizontally.
NOTE: If a student had a transcription error in the contingency table, this is not to be penalized in Question 1 and Question 2 unless a new error is made with these values.	
Question 1: **The intention of this question is to calculate a simple probability and recognize the organization of responses from the vertical portion of a contingency table.**	
E	The student has correctly found the probability and expressed the result in the form of a percentage, decimal, or fraction.
P	The student has only found the total of the column and fails to recognize that a probability is a part out of a total *or* has made a minor error in addition while showing the work to arrive at the response.
I	The student has made errors without showing work *or* fails to show an understanding of the addition of the column.
Question 2: **The intention of this question is to calculate a simple probability and recognize the organization of responses from the horizontal portion of a contingency table.**	
E	The student has correctly found the probability and expressed the result in the form of a percentage, decimal, or fraction.
P	The student has only found the total of the row and fails to recognize that a probability is a part out of a total *or* has made a minor error in addition while showing the work to arrive at the response.
I	The student has made errors without showing work *or* fails to show an understanding of the addition of the row.

AfterMath Task 3 Rubric

Question 1: **The intention of the question is to use the addition rule with one result in the column and one result in the row where an intersection occurs in the responses.**	
E	The student correctly found the compound probability using the addition rule and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly performed the numerator portion of the addition rule but eliminated the denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with the addition rule.
Question 2: **The intention of the question is to use the addition rule with independent events.**	
E	The student correctly found the compound probability using the addition rule and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly performed the numerator portion of the addition rule but eliminated the denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with the addition rule.
Question 3: **The intention of the question is to use the addition rule with one result in the row and one result in the column where an intersection occurs in the responses.**	
E	The student correctly found the compound probability using the addition rule and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly performed the numerator portion of the addition rule but eliminated the denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with the addition rule.
Question 4: **The intention of the question is to use Bayes' Theorem to calculate a conditional probability and recognizing the favorite restaurant variable as the condition.**	
E	The student correctly applied Bayes' Theorem to find the conditional probability and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly identified the numerator of the probability calculation but failed to apply the condition to the final denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with Bayes' Theorem.
Question 5: **The intention of the question is to use Bayes' Theorem to calculate a conditional probability and recognizing the student location variable as the condition.**	

E	The student correctly applied Bayes' Theorem to find the conditional probability and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly identified the numerator of the probability calculation but failed to apply the condition to the final denominator.
I	The student incorrectly calculated the probability by using a rule not consistent with Bayes' Theorem.
Question 6: The intention of the question is to use the multiplication rule to find a probability when more than one subject is selected from a sample.	
E	The student correctly applied the multiplication rule to find a probability with or without replacement and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly identified only one of the two probabilities without multiplication and displayed the result in the form of a percentage, decimal, or fraction.
I	The student incorrectly calculated the probability by using non-multiplicative methods *or* provided an otherwise incorrect probability.
Question 7: The intention of the question is to use the multiplication rule to find a probability when more than one subject is selected from a sample in combination with a condition of student location.	
E	The student correctly applied the multiplication rule to find a probability with or without replacement, used the student location, and displayed the result in the form of a percentage, decimal, or fraction.
P	The student correctly applied the multiplication rule to find a probability with or without replacement or correctly used the student location condition (but not both) *and* identified only one of the two probabilities without multiplication and displayed the result in the form of a percentage, decimal, or fraction.
I	The student incorrectly calculated the probability by using non-multiplicative methods and did not properly use the condition of student location.

AfterMath Task 4 Rubric

Question 1: The intention of the question is to calculate a compound probability from a summary demographic data set and recognize which given probabilities are totals of subcategories.	
E	The student has correctly found the probability using addition and expressed the result in the form of a percentage, decimal, or fraction.
P	The student used addition to combine categories but misread at most one subcategory as a main category.
I	The student incorrectly calculated the probability by adding subcategories and main categories multiple times or through other means.
Question 2: The intention of this question is to calculate a compound probability after correctly identifying the information for the state in question.	
E	The student has correctly found the probability using addition and expressed the result in the form of a percentage, decimal, or fraction.
P	The student used addition to combine categories but misread at most one subcategory as a main category *or* used data from the incorrect state line.
I	The student incorrectly calculated the probability by adding subcategories and main categories multiple times or through other means.
Question 3: The intention of this question is to calculate a compound probability after correctly identifying the information for the territory in question.	
E	The student has correctly found the probability using addition and expressed the result in the form of a percentage, decimal, or fraction.
P	The student used addition to combine categories but misread at most one subcategory as a main category *or* used data from the incorrect state line.
I	The student incorrectly calculated the probability by adding subcategories and main categories multiple times or through other means.

AfterMath Task 5 Rubric

<table>
<tr><td colspan="2" align="center">Question 1:
The intention of the question is to recognize what constitutes a response to demographic information.</td></tr>
<tr><td>E</td><td>The student identifies the characteristics of their household in the context of the variables from Task 4.</td></tr>
<tr><td>P</td><td>The student identifies household characteristics but does not include the inquired about demographic information that links to Task 4.</td></tr>
<tr><td>I</td><td>The student makes unrelated responses to the demographics at hand.</td></tr>
<tr><td colspan="2" align="center">Question 2:
The intention of this question is for the student to draw inferences about ethnicity and location in terms of household composition and make comparisons between themselves and the Task 4 data.</td></tr>
<tr><td>E</td><td>The student brings in their information and the variables from Task 4 into their response.</td></tr>
<tr><td>P</td><td>The student uses variables from Task 4 to make conclusions or uses only their information.</td></tr>
<tr><td>I</td><td>The student makes superficial or irrelevant inferences for the data.</td></tr>
</table>

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