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Preservice Teachers' Use of Mathematics Pedagogy to Conceptualize Distortion in World Maps

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Abstract:

This research study focuses on preservice teachers' (n=66) inspection of pedagogical connections between geography and geometrical reasoning. The aim of this study was to empirically investigate the use of mathematical analysis to enrich the social studies topics of the distortion of country sizes on the world map. The analysis of data collected from the 66 participants generated seven specific pedagogical strategies and covered nine identified mathematics and social studies topics during their lesson concepts for introducing the world map to elementary students. Results from this study reveal that after being corrected regarding this misconception, the participating preservice teachers were successful in developing learning activities to address this topic, employing student-centered strategies including technology-based, paper-based, hands-on, and feet-on approaches.

Keywords: social studies education, mathematics education, geography education, teacher education, interdisciplinary teaching

Introduction

Geography is a subject that allows students to explore their own living planet, from continents to their local streets, as well as how these components are dynamically structured and interact

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(Hinde et al., 2007). Maps shrink this complexity into a transferrable and succinct picture and therefore have become one of the chief representational modalities for illustrating and communicating geographical information, particularly within the K-12 geography curriculum. Most regional maps provide fairly accurate information regarding relative sizes of geographic features—for example, a map of the United States shows Texas to be about four times the size of Oklahoma—and thus the visual sizes displayed match up with their relative sizes in reality. Conversely, a flat world map will always have a degree of nontrivial distortion, with the types and severity of distortion determined by the projection system employed during the selected process for converting the spherical surface of the Earth into a two-dimensional and generally rectangular representation. A typical example of such misrepresentation is the size of Greenland, which is visually equivalent to the whole continent of Africa on most classroom world maps, although in reality the geographical size of the African continent is roughly 14 times larger than that of Greenland. To represent Earth's entire surface accurately on a two-dimensional map would require that the actual Earth be a two-dimensional surface, which it is not, and so the use of complex conversion processes for transferring spheroidal objects onto flat projections will continue to be inevitable, along with the distortion they entail.

Through the lenses of critical geography, and more specifically critical cartography, these inaccuracies and others can be explored further. Both critical geography and critical cartography are practices grounded in critical theory and thus actively acknowledge that maps in general are not objective realities but instead often reflect the interests of the institutions that created them, the historical contexts in which they were developed, and the idiosyncrasies related to individual cartographers (Au, 2022). According to Crampton and Krygier (2010), critical cartography assumes that maps can essentially create new realities despite their intended goal of representational authenticity. Because maps are dynamic and cartography can construct knowledge, the products of cartographers can either be employed to uphold existing dominant political structures and norms or, on the contrary, promote social change.

Historically, the most popular world mapping system has been the Mercator projection, which has been widely adopted across many countries particularly in terms of use within classrooms and atlases. The Mercator projected world map is basically a flattened cylindrical map, similar to placing a marble into a cylindrical cup and then printing the marble's pattern on the cup's outer wall. The Mercator mapping system has been demonstrated to provide suitability for marine navigation in comparison with some of the other popular types of projected maps, in particular because the Mercator system allows positions to be calculated via constant bearing

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as a straight segment. The downside of the Mercator map is that the regions in high latitudes such as northern Europe, North America, and Russia become increasingly enlarged as they near the top edge of the rectangular map; the distortions near the bottom of the map mostly impact Antarctica and are therefore less of a concern for geographers. Yet such inaccuracies in the presentation of geographic sizes on Mercator world maps are rarely mentioned in social studies or history classes that employ such maps, and therefore many students—along with adults—develop life-long misconceptions about the relative sizes of key geopolitical countries (Cormas, 2009).

Marginalization of Social Studies in Elementary Education

Researchers have previously noted that social studies education was continuously marginalized throughout the K-12 curriculum for the past 30 years. Specifically, the adoption of the No Child Left Behind Act (NCLB) and Common Core State Standards (CCSS) were two major driving forces that actively sidelined the position of social studies within the K-12 curriculum (Aktan, 2016; Heafner, 2018; Kenna & Russell, 2015; Waters & Watson, 2016). While NCLB increased accountability via state-level standardized testing, school subjects such as mathematics and reading were prioritized during instructional time whereas subjects such as social studies were given less focus (Fitchett & Heafner, 2010; Pace, 2012). Likewise, social studies was essentially excluded from CCSS, while the subjects of mathematics and language arts were given primacy (Heafner, 2018; Waters & Watson, 2016). The collective result of NCLB and CCSS was thus a substantial decrease in the instructional time allotted for social studies across students' regular academic time (Fitchett, Heafner, & Lambert, 2014; Strachan, 2015).

The marginalized status of social studies within the K-12 curriculum is not expected to change in the foreseeable future, and so the integration of social studies instructional opportunities into the "core" subjects such as literacy, math, and science has been identified as a crucial method for providing social studies content knowledge to students (Heafner, 2018; Huck, 2018; Kinniburgh & Busby, 2008). As a partial remedy for addressing the issue of inadequate instructional time for social studies (Castro, Field, Bauml, & Morowski, 2012), the methods employed for embedding social studies into language arts and mathematics can offer students pedagogy focused on connecting knowledge across subject boundaries during student-centered and project-based activities (Anderson, 2014; Holloway & Chiodo, 2009). Without proper professional development, however, many teachers will remain unaware of the interdisciplinary teaching opportunities available to highlight social studies in their language arts and mathematics lessons (Cashman, 2021; Harris, Wirz, Hinde, & Libbee, 2015).

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Pedagogical Connection of Maps with Elementary Curriculum

As a useful component within many fields of education, maps are frequently embedded in written texts to serve as supplementary visual information (McCall, 2011). A wide range of classroom topics can be accessible with maps, including, for example, science lessons from biology and environmental science, both of which can use maps to display animal-habitat relationships around the world such as pandas in central China, kangaroos in Australia, or penguins in Antarctica (Aikenhead, 2001). In early childhood literacy education, maps have been used during educational strategies employing picture books to help children pinpoint the relative locations in the stories (Kümmerling-Meibauer, 2010). During dance and physical education classes, maps have been used to help individual students become aware of their positions within a large group dance or team sports (An, Tillman, & Hachey, 2021). In political science and civic classes, maps have been utilized to illustrate the complexity of gerrymandered voting districts, divisions along county-city boundaries, and the growth of public transportation systems (Bar-Natan, Najt, & Schutzman, 2020).

Regarding the role of maps in mathematics education, maps are both cognitively and instructionally entangled with mathematics pedagogy. Researchers that have studied and identified the processes responsible for mapping within cognition have found that they are associated with the same mental processes occurring during mathematically oriented thinking (NCTM, 2000, 2006). Specifically, both map-cognition and mathematical-cognition require students to (1) understand and apply new sets of symbols, (2) conceptualize objects through multiple perspectives (e.g., 2D versus 3D, algebraic versus geometric), (3) develop a sense of measurement, (4) use coordination systems to determine positions, (5) make scale adjustments based on proportional thinking, and (6) transition between physical and abstract representations.

Nevertheless, interdisciplinary educational opportunities that connect mathematics with mapping have generally been neglected by classroom teachers. Previous research studies that have examined the use of maps during mathematics instruction has primarily focused on the teaching of projection to geology majors during undergraduate education (e.g., Basaraner & Cetinkaya, 2019; Savric, Patterson, & Jenny 2019); research empirically investigating the appropriate pedagogy for introducing world maps and their projection systems to K-12 students is generally absent. The purpose of the current research study is to examine preservice teachers' instructional strategies for helping their students understand different projection

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systems for displaying a world map, with special emphasis on pedagogy employed to explain distortions to country sizes within Mercator world maps.

Specifically, this study aims to answer the following two research questions:

(1) How did the participating elementary preservice teachers respond to learning about the distortion within Mercator projected world maps?

(2) What were the participating elementary preservice teachers' instructional strategies for delivering lessons about world map distortions to their students?

Methods

Research Setting and Participants

The current study was conducted in the Southwestern region of the United States, and included a total of 66 preservice elementary teachers, each of whom was enrolled in a one-year residency program during which they practiced clinical teaching in local schools while guided by field supervisors. The participants in this study were predominantly female (n=61) and Hispanic (n=63) and had enrolled in a mathematics methods and a social studies methods course concurrently. All participants had also completed prerequisite mathematics content and social studies content courses earlier during their freshman and sophomore years.

Description of the Learning Task

The main preparatory activity prior to data collection was to introduce a web-based interactive world map software called "*The True Size Of ...*". This software was created by James Talmage and Damon Maneice for the educational purpose of helping teachers to demonstrate how latitude impacts country size on a world map. Specifically, the software enables students to drag a country from its regular geographic position on the Mercator world map to a different latitudinal position; for example, Norway can be moved to the equator to see how its apparent size shrinks, showing students the patterns of geometric distortion caused by the cylindrical projection systems. For this study, the continents of North America and Africa were selected as the two foci for the tasks the participating preservice teachers would undertake while mathematically examining country distortions on the Mercator world map. The rationale for choosing these two continents was that North America was familiar to all of the participants because that is where they lived, and Africa is one of the continents with the least amount of distortion on a traditional Mercator map.

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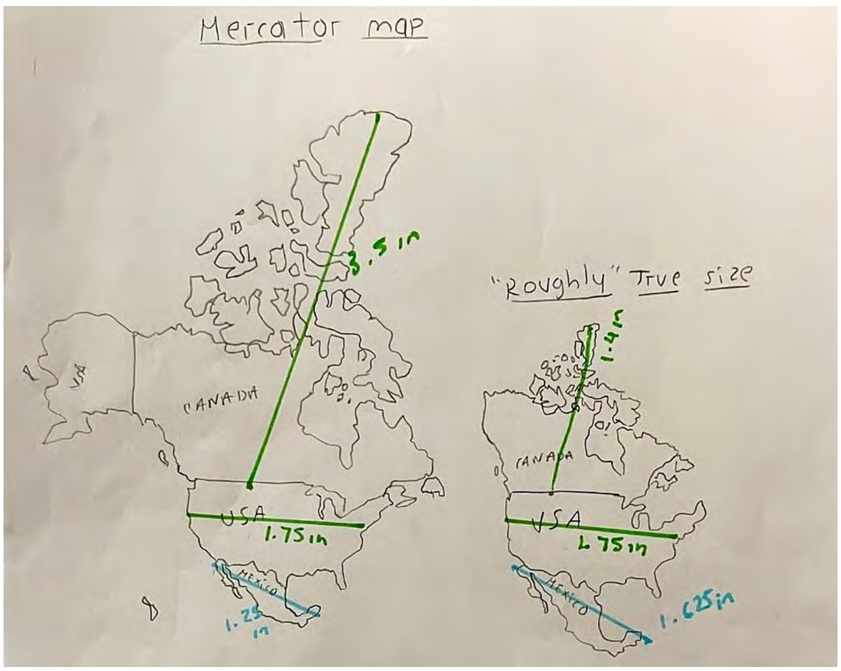
During the task focused on North America (see Figure 1), the preservice teachers were asked to develop a new map showing the correct relative sizes among Canada (which is significantly enlarged on a Mercator world map), the United States (which is somewhat enlarged on a Mercator world map), and Mexico (which accurately displays its real size on a Mercator world map). Then, during the task focused on Africa (see Figure 2), the preservice teachers were asked to find two or more means of selecting a group of non-African countries that roughly matched the size of the African continent.

Figure 1

Sample drawings of North America created by one of the participants



Data Collection and Analysis

A total of 66 reflective essays were collected from the participants. The content of the essays generally included three paragraphs corresponding to the following three questions: (1) What is your understanding of Mercator world map distortions for country sizes? (2) Do you think mathematics can help explain such distortions, and why or why not? (3) What are your teaching strategies for explaining the world map's distortions of country sizes? The average word counts for the collected essays were 438 words each, upon which the grounded theory approach was

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utilized as the major data analysis technique (Corbin & Strauss, 2008). Emergent themes across the data were identified and consistency was compared and iteratively refined until the main categories and subcategories were saturated. To ensure reliability, the data was independently coded by three researchers, and inconsistencies were resolved collectively by group dialogue and decision making.

Figure 2.

Sample drawings of African continent from one of the participants

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Results

The analysis of data collected from the 66 participants generated seven specific pedagogical strategies and covered nine identified mathematics and social studies topics during their lesson concepts for introducing the world map to elementary students (see Table 1). Each of the participants proposed methods for demonstrating the world map distortion patterns, including: (A) computer-based approaches from 53 participants (80.3%), (B) paper-pencil based approaches from 60 participants (90.1%), and (C) hands-on based approaches from 29 participants (43.9%). Nine different mathematics topics were covered in the collected lesson plans, ranging from “number and operation” to “ratio and proportion” topics. Measurement and geometry were the mathematics content areas most frequently addressed, 52 times (78.8%) and 35 times (53.0%), respectively. To illustrate the instructional strategies employed, the lesson plans of seven participants—Belinda, Natalia, Emiliano, Gia, Sofia, Martina, and Carmen (pseudonyms)—were selected as demonstrative of the most important representative features.

Pedagogy for Helping Students Conceptualize Map Distortions

While almost all of the participants acknowledged computer simulations during their design of teaching methods, especially during the first stage of their lessons, only a small portion of participants (16.7%) proposed showing a video to their students; the general method proposed was to find pre-existing educational videos from media sharing websites and play these videos in class to their students. As a demonstrative example, Belinda presented an instructional design that employed steps that included having students first watch a video and then participate in follow-up activities using hands-on manipulatives to measure and compare country sizes. Belinda described her lesson as follows:

> If I had the chance to show my students a map of the world, I could show the misrepresentation of size by playing a video from YouTube that talks about the size of the United States compared to Canada or Mexico. Then, I would guide my students to look at the map together and see if the map is accurate or not based on the actual size of the United States. To help my students learn the true size of different countries, I would assign one country to each student and they would have to research the exact size of their country in square miles. We would then use 10 small cubes to represent one million square miles and the students would have to make a model of their country

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that is “true” to size using the blocks. This would help them to see what true size may be represented as.

Table 1

Pedagogical Approaches and Content Foci for Addressing World Map Distortions

Teaching Methods and Contents		Occurrences	Rates
Teaching Methods	Computer simulation through existing videos	11	16.7%
	Computer simulations by teacher	27	40.9%
	Computer simulations by students	15	22.7%
	Paper-pencil activities (fixed comparison)	38	57.6%
	Paper-pencil activities (open comparison)	22	33.3%
	Hands-on activities with manipulatives (2D only)	19	28.8%
	Hands-on activities with manipulatives (3D and 2D)	10	15.2%
	Feet-on activities	3	5.0%
Content Coverage	Historical background	29	43.9%
	Alternative types of projections	17	25.8%
	Data collection	25	37.9%
	Geometry (shapes, locations and dilation)	35	53.0%
	Measurement (area and size comparisons)	52	78.8%
	Number and operation (addition, multiplication, division, fractions and percentages)	26	39.4%
	Ratio, scale and proportion	30	45.5%
	Algebra (equations)	8	12.1%

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Belinda's hands-on activities featured assessments of the relative sizes of different countries compared to a fixed reference: the size of the United States. By contrasting the number of equal-sized blocks that covered the United States versus other countries, Belinda's students were able to quantify country size differences. Different from Belinda's approach, which emphasized manipulatives-based activities, Natalia developed her instructional strategy by emphasizing the process of drawing. In Natalia's lesson, students were asked to draw a map based on their mental conception of relative country sizes and re-draw the same map after learning the correct relative sizes from a reliable online source. Specifically, Natalia said:

> I would have my students pick out a country and have them draw it as it is represented on a regular map. After that, they can log on to the website of TrueSize and then draw it out as it is represented on there. From a mathematical standpoint, I would like my students to look for the square miles of at least two countries, like Mexico and France, and then compare them to the size displayed on a regular map, and then again on the TrueSize website. This will allow them to see which of two maps represents the size correctly based on numbers. My students can draw the countries out with shapes, as I think it is a fun activity that could work for both social studies and math.

Natalia's lesson plan encourages her hypothetical students to compare country sizes by dragging a pair of countries to the same latitude on a digital world map, and this experience was designed to result in the drawing of maps with superior precision. Similar to Natalia, participant Emiliano also proposed a lesson that encouraged students to use digital software to investigate the relative sizes of different countries. However, unlike Natalia, Emiliano prepared additional materials intended to highlight the mathematical concepts behind the Mercator world map projection system as well as the historical and political context in which it was developed. Emiliano specified his instructional process as follows:

> … my students need to peel an orange and extend it into a flat shape. After discussing how difficult it is, I would ask them if they think it is easy to represent the Earth (or any planet) into a 2D shape. After that, I would introduce them to the website of thetruesize.com so they can start comparing the different countries and make observations on them. Some of the observations that I would like them to think about is why is Europe in the center of the world and whether or not they think it is on purpose. I would also present my students world maps used in different parts of the world such as Australia where they put Australia in the center of the world, and analyze the importance of representing our countries in a certain way.

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Emiliano's lessons featured a mapmaking process that allowed his students to create maps by placing different countries as the center of a Mercator projected world map and observing how this impacted the relative sizes of the countries. In comparison, participant Gia attempted to go beyond the Mercator route by introducing her students to maps employing other types of projection systems. Within her instructional strategy, the common use of Mercator maps was compared with mapping systems that show accurate country sizes but must employ other compromises to fit a spherical surface onto a flat plane. Gia described why she believed that having students make comparisons among multiple projection systems for mapping may help them understand why there is distortion within flat world maps. Gia stated:

> I am going to make sure I get one [Mercator] world map that has misrepresentation and another type of projections such as the Dymaxion map and Gall-Peters map that has an accurate representation of country sizes of our world. I would plan activities for my students to compare the sizes of countries in the maps with different projections for them to understand why none of the maps is perfect and we cannot fully rely on any single resource to know about areas of countries or continents. It will really help them see and understand how each map shows different things and the strength and weakness of each type of map. Analyzing and comparing "accurate" and "compromise" maps is one of the strategies that I would use to help students realize the limitation of maps.

Although the use of digital technology such as the TrueSize online mapping software was found extensively across the analyzed instructional strategies, some of the participants decided to use digital technology in other ways. One of the participants, Sofia, proposed instruction that offered hands-on activities followed by statistical examination. Sofia described how having students compare country sizes using bar graphs that show the relative areas could supplement the visually oriented comparisons of the countries' borders and internal areas on maps. As Sofia described:

> I will show a picture of a standard Mercator map and put a picture of each continent with actual size on the Mercator map. This will help the students get an overall visual representation of the correct size of each continent… I can show my students a bar graph that represents the size of [selected] countries from smaller to largest. My students will develop a more accurate view of size [of countries] based on square mileage or kilometers rather than visual representations. I would also help my students

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> understand how to find the right scale by presenting fraction, ratios, and proportions in constructing the world map with correct country sizes.

Similar to Sofia's teaching approach, which emphasized statistical data analysis and the use of bar graphs to compare ratios, Martina also contributed an advanced pedagogical approach by asking students to make pie charts representing the countries on grid-based world maps, helping them to transition between multiple representations of the data they were investigating. Martina further developed the learning activities for her students by having them make world maps with carboard and Play-Doh, based on their previously created grid-maps. As Martina specified:

> I would give my students graph paper to draw their new maps based on squares. I would set the entire land on the earth to equal 100% and have the students arrange the countries within 100 squares on the graph paper. This will give them the opportunity to identify and sort the top 20 largest countries together with the rest of the world in a pie graph. Students would calculate the percentage of each country and then assign the percentage in the graph paper until they all add up to 100%. This means that the students should determine the country sizes by counting the number of squares on their graph paper. The follow-up activity I thought about was having them make the countries out of clay or Play-Doh. When they are done, they can have a gallery walk and compare between their Play-Doh maps.

Unlike most of the participants, who generally employed traditional instructional resources during their lessons, Carmen was one of the few participants who employed full-body kinesthetic learning activities to help her students conceptualize the Mercator world map projection system. In Carmen's instructional plans, a physical sandbox was employed and her students were expected to draw the relative sizes of different countries in the sand, using their finger or a stick as the drawing tool. Carmen also provided a learning activity during which the whole class participated in kinesthetic movement around the room while comparing country sizes. She stated:

> My students will be able to identify how each country looks like by drawing out the countries themselves in the sandboxes… I would also use the same concept of students creating their maps by playing a grid-game. I would set up strings on the floor where they form a grid and the students would walk around the grid to represent the size of a country they are assigned. As a class they can help each other. For example, if the

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> [continent] North America were 4 squares by 6 squares, then 10 students will walk together represent the size of the Canada, another 10 students to represent the size of United States, and 2 students to represent the size of Mexico.

Post-Debriefing Reflections on the Distortions in World Maps

According to Cormas (2009), "displaying a single world map in the middle school classroom (often some version of a political map and a Mercator projection) has contributed to student misconceptions in geography and Earth science" (p. 8). It is not uncommon for preservice teachers to confuse common directional terms (up, down, right, and left) with cardinal directions (north, south, east, and west). Moreover, within the Mercator projection system, landmasses may be depicted inaccurately, such as Greenland appearing to have a greater land mass than South America. Even more disconcerting is the tendency among some preservice educators to "assert information gleaned from a map as if it were infallible and complete" (p. 8).

In general, the participants agreed that the learning tasks changed their perceptions toward social studies teaching, and they acknowledged the value of integrating mathematics into the presentation of social studies concepts. One of the predominant themes that was repeatedly expressed in the collected reflection essays was their feelings of frustration at being misled by the common Mercator world map system. Most participants stated that they had never been taught about distortions based on a world map's projection system, and participating in the current study allowed them to develop a better understanding of how to go about creating effective pedagogy for addressing this topic with their own students in the future. By mathematically and visually deconstructing the world map into accurately sized countries, the participants learned about the types of distortion that occur when a projection system is selected. As an illustration, Gia shared her insights into how she transformed her perceptions and pedagogy toward world maps:

> The map is all lies! This gave me a major existential crisis. I was astonished to learn how political reasons such as Western imperialism and Eurocentrism have deceived us into thinking that maps provide an accurate depiction of countries. After looking at the actual representations of sizes of countries, I learned the valuable lesson of not trusting everything I see because it can be easily distorted. As future teachers, it is our job to teach our students that the map we have is wrong and it can be proven that is wrong… It might take some time to get the real and exact measurement of each country. But it

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> will help [students] know the true size of each country and make a new map according to the correct size.

Likewise, Belinda shared her newfound understanding about the importance of developing and implementing interdisciplinary education that connects social studies with mathematics to help students avoid incorrect conceptions. For Belinda, the key pedagogical transformation in her mindset was to realize that by highlighting geography in the social studies curriculum, she could make links between geography and mathematics during the teaching process. As Belinda commented:

> I was never aware that there exists misrepresentation of size [of countries] on world map. Teachers explained which [countries] are bigger but no one, at least in my experience, showed me a visual representation of it. I was shocked when I read the information provided about the errors on the world maps we see in the classrooms. It also made me realize that when learning about all these different countries, I have completely disregarded one very important part: geography. The location and actual sizes of these components that make our planet are essential to really understand these places and their relationships between humans and the environment.

Emiliano also articulated during his reflections that, similar to Gia and Belinda, the experience of investigating country size distortions in world maps had reshaped his teaching philosophy. Specifically, Emiliano pointed out that not only will he address critical thinking during his teaching process, he will also facilitate and encourage future students to make their own verifications of whatever they are taught. Emiliano described what he learned and how it changed his approach to teaching:

> Something that was very provoking for me was that the Mercator map is the most widely used map in the world. This is the map that may be found in the schools through the world. I feel betrayed. In my whole life, I thought the countries that were shown in the world map were an accurate size. It is astonishing [for me to know] the nations around the poles are depicted as considerably larger than they are in reality. So, I believe that as teachers it is our responsibility to give our students correct information.

Discussion

This research study focused chiefly on the participating preservice teachers' investigation of pedagogical connections between social studies and mathematics as a means for enriching

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social studies education. Specifically, the aim of this study was to examine empirical evidence of mathematical thinking, such as proportional and geometrical reasoning, within participating preservice teachers' instructional strategies for explaining the distortion of country sizes within Mercator-projected world maps. The findings from the current study were consistent with previous studies on social studies and mathematics integration within education (An & Tillman, 2018; Maguth, 2012) showing that preservice teachers were generally underprepared to employ mathematics during their instruction of social studies concepts. A majority of the participants in this study acknowledged that they had assumed the traditional Mercator world map was accurate regarding country sizes. Results from this study revealed that after being corrected regarding this misconception, the participants were successful in developing learning activities to address this topic, employing student-centered strategies including technology-based, paper-based, hands-on, and feet-on approaches.

Analysis of the participants' instructional designs revealed their processes for teaching the topic of world map distortion regarding country sizes. A wide variety of mathematical activities were created by the participants during their lessons explaining the distortion of countries in high latitude regions, such as Canada and Russia. These activities offered a variety of options for displaying the relative sizes of different countries, including the use of dynamic digital maps on computers, drawings on paper, cubes on a table, Play-Doh spread on cardboard, statistical graphs, and even choreographed movement. Many of the participants included more than one type of medium, thus employing multiple representations in their pedagogy.

A wide range of mathematical topics was integrated into the participants' instructional approaches for teaching about world map projection systems. The use of mathematics to help explain the distortion of country sizes, especially the deformations that occur within Mercator system world maps, enabled the participants to develop lessons featuring interdisciplinary connections. The empirical findings from this study demonstrate some of the potential for maps to help teachers find connections between mathematics and geography. Each of the overarching topics within mathematics, such as number and operation, geometry, measurement, algebra, data analysis, and probability, can provide resources for better understanding maps and mapmaking, thereby supporting interdisciplinary approaches to social studies and geography education.

This study also investigated the implementation of student-centered teaching methods appropriate for supporting interdisciplinary instruction in the social studies classroom. Social studies knowledge was systematically linked with mathematics so as to encourage students to

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develop a better understanding of how a country's size can be quantitatively analyzed; a similar approach could be used to teach other geographic information including aspects of population, economics, currency, temperature, transportation, energy use, and many other quantifiable variables. The inherently quantitative nature of most social studies data collection and analysis might even indicate that many social studies concepts cannot be accurately conveyed without mathematics. Nevertheless, the majority of traditional pedagogical approaches to teaching social studies still focus on memorization of facts and definitions, which are then assessed during multiple-choice timed tests (Stohlmann, 2018). To improve the teaching of social studies, it is therefore crucial to provide preservice teachers with interdisciplinary pedagogical techniques that encourage students to construct their own internal knowledge networks regarding understanding of social studies.

Before transitioning to the conclusion, several limitations to this study's research design should be acknowledged. First, this research study employed an ethnically homogenous group of participants containing a majority that were Hispanic female college students. Because of the homogeneity of the participants, any conclusions from this study are limited in their generalizability. In addition, no assessments were conducted prior to the study to evaluate participants' content knowledge and pedagogical capacity in either mathematics or social studies. Therefore, it is difficult to discern what (if any) impacts were a direct result from the intervention, as opposed to a pre-existing understanding regarding the interdisciplinary links between mathematics and geography. Both of these limitations will be addressed in future studies by our research team, and it is our hope that other research teams might also be interested in empirically investigating these topics with research designs that specifically tackle these challenges. Despite these limitations, the current study empirically analyzed the preservice teachers' development of teaching strategies that highlighted interdisciplinary connections between social studies and mathematics. To further develop this line of research, the authors encourage further systemic investigation of preservice teachers' changes in effectiveness and self-efficacy at teaching interdisciplinary lessons combining social studies with mathematics, as well as impacts on students' learning that results from classroom teachers implementing such interdisciplinary pedagogy.

Conclusion

A best-selling children's picture book, *Oh, the Places You'll Go!* written and illustrated by Dr. Seuss (1957), presented a misleading world map illustration showing readers a South America that was visually equivalent to the United States in size. Dr. Seuss's books were well-known for

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their creative liberties and distortions of reality, so perhaps a world map based on the Mercator system was appropriate within that context. But there was nothing special or unique about Dr. Seuss's use of this world map projection system within his book; instead, similar maps based on the Mercator projection system can be found anywhere from commercial products to educational resources. Without geography education employing mathematical analyses, students and their teachers might never learn that the most common world maps intentionally distort the actual sizes of some countries. After years of repeatedly seeing these distorted map projection systems in a wide variety of settings and contexts, such representations can become especially challenging to correct. The use of projection systems for converting our spherical world into a flat, generally rectangular map has resulted in geographic misconceptions about the sizes of Africa and Central and South America, as well as portions of Asia, all of which were significantly shrunk on the standard Mercator world map. Furthermore, countries like Canada, Greenland, and Iceland were vastly oversized, giving students an inaccurate understanding of these nations' physical presence on the globe. The Boston Public Schools system has attempted to address this educational issue, announcing in 2017 that their schools were replacing Mercator world maps with Gall-Peters projected maps, which more equitably size non-Western countries; however, the vast majority of school districts in the United States continue to use the Mercator projection system for their standard world maps across the curriculum.

A core component of modern social studies education is learning to think from an empirical rather than a subjective perspective (Hawkman, 2020). For example, Cormas (2009) recommended that students be supported in developing understanding of the following key social studies concepts: (1) Maps are simplified representations of an infinitely complex reality; (2) Maps are tools that can be used for a wide variety of purposes; (3) Maps are created by mapmakers and therefore can contain intentional as well as unintentional misconceptions and biases. But in order for students to be taught these concepts, more teachers will need to acquire pedagogical aptitude for meaningfully integrating mathematics into their social studies lessons (Martignon & Krauss, 2009). The results from this study suggest that teacher education programs would benefit from the identification and piloting of interdisciplinary approaches to preservice teacher preparation, particularly those approaches that highlight connections between mathematics and social studies instruction. As an alternative to traditional social studies instruction that is often based on isolated, fragmented, and abstracted information, an interdisciplinary approach employing mathematics activities may help students better understand both social studies and the world in which it is taught.

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