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ABSTRACT

This paper examines the differences between student performance on two separate measures, the Spatial Visualization portion of the "Differential Aptitude Test" and the "Geometry Content Knowledge Test." Results from the hybrid quantitative/qualitative study indicate that although there were no differences in performance on spatial visualization for males and females or across ethnicities, differences in performance on geometry content knowledge tasks for ethnicity were evident. (Contains 35 references.) (Author/ASK)

Running head: PERFORMANCE ON SPATIAL VISUALIZATION AND GEOMETRY

Exploring the Influences of Geometric Spatial Visualization, Gender, and Ethnicity on the Acquisition of Geometry Content Knowledge

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Abstract

This paper examines the differences between student performance on two separate measures, the Spatial Visualization portion of the Differential Aptitude Test (Bennett, Seashore, & Wesman, 1973) and the Geometry Content Knowledge Test (Carroll, 1998). Results from the hybrid quantitative/qualitative study indicated that although there were no differences in performance on spatial visualization for males and females or across ethnicities, differences in performance on geometry content knowledge tasks for ethnicity was evident.

Exploring the Influences of Geometric Spatial Visualization, Gender, and Ethnicity on the Acquisition of Geometry Content Knowledge

Introduction

There have been numerous studies indicating differences in mathematics performance for males and females (Allen, 1995; AAUW, 1991; Baenninger & Newcombe, 1989; Connor & Serbin, 1980; Fennema, 1975). These studies were followed by further research (Hyde, Fennema, & Lamon, 1990) indicating that no "real" differences existed in mathematics by gender. Spatial skills have been shown (Casey, Nuttall, & Pezaris, 1997) to be an area in which achievement differences exist between males and females. Mitchelmore (1976) found that youths in Jamaica performed differently on spatial visualization tasks than similar studies reported on American youth.

Geometry Content Knowledge

> "Until recently, the geometry curriculum in the United States has been very poorly defined. Children in the early grades learned to identify a few basic shapes. Beyond that primitive bit of knowledge, teachers have had little guidance on what is important. However, the work of two Dutch educators, Pierre van Hiele and Dina van Hiele-Geldorf, is beginning to have an impact on the design of geometry instruction and curriculum" (Van de Walle, 1998 p. 345).

Dina van Hiele-Geldorf (1984) found a seemingly natural progression of development of geometric skills in children. These researchers (van Hiele, 1987) maintained that this progression of geometry and of geometric spatial visualization could be taught using a hierarchical sequence of five levels, going from classes of shapes (Level 0), properties of shapes (Level 1), relationships among properties of shapes (Level 2), deductive systems of properties of shapes (Level 3), to the analysis of deductive systems of shapes (Level 4). At each level of geometric thought concepts formed became the object of thought at the next level. These five levels were based on van Hiele-Geldorf's previous research which established four levels.

Predating the van Hieles, Jean Piaget (Piaget, Inhelder, 1956) observed geometric development in children. Piaget, Inhelder and Szeminska (1964) stated that students began to demonstrate geometry and spatial concepts in visual stages that were closely related to van Hiele-Geldorf's Level 1. These researchers also proposed several levels of geometric conception that enjoy wide acceptance today. The researchers believed that students achieved learning goals and demonstrated certain competencies relevant to age and experiences in accordance with each level attained. They believed that children progressed at their own pace, some more rapidly than others, and some not at all. The researchers noted that females often lagged behind males in these age groupings/levels. In support of the research of Piaget and the van Hieles, Clements, Swaminathan, Hannibal, and Sarama (1999) believed that young children exhibit visualization based on a two-dimensional coordinate system emphasizing the connection to Level 1.

Battista (1999, 1998) found that as students attempt to move from two-dimensional coordinate systems to displays of three-dimensions, they first represent the real objects as poorly defined arrays and then with more experience, begin to organize the objects into a cohesive array of units. Battista (1999) further stated that as students developed an understanding of two- and three- dimensional space, the visual and rotational components of spatial sense developed at varying rates.

Students who were more advanced in basic geometric knowledge progressed more rapidly in spatial and reasoning skills than their peers.

Mathematical curriculum in the elementary school is often dictated by the content of standardized tests. According to Underhill (1990), teachers focused instructional time on teaching computation because standardized tests and competencies evaluated students on their ability to perform these computations. As long as the focus remained on algorithms, geometry was allocated little instructional time. Geometry and spatial sense did not lend themselves easily to algorithmic form. Even though today, geometry is being added to standardized test batteries, spatial visualization is not experiencing the same level of inclusion.

The view of shape is critical to geometry content knowledge. When the view of shape is developed and how the view of shape is developed may indeed lead to success in components of spatial sense. Clements, Swaminathan, Hanibal and Sarama (1999), indicated that participants as young as six matched shapes to visual prototypes rather than attributes. The researchers further postulated that children at the prerecognitive level were just starting to form schemas connecting geometric concepts to spatial visualization.

Bringing geometry to the forefront in the elementary classroom, the *National Council of Teachers of Mathematics Principles and Standards for School Mathematics* (NCTM, 2000) states that by sixth grade students should be able to: (a) analyze characteristics and properties of two and three-dimensional objects, (b) recognize the usefulness of transformations and symmetry in analyzing mathematical situations, and (c) use visualization and spatial reasoning to solve problems both within and outside of mathematics.

Spatial Visualization

Tartre (1990) defined spatial visualization as the ability to predict specified transformations of geometric figures. Visualization was described as the collective abilities of reasoning, figural classifications, and figural relations.

Casey, Nuttall, and Pezaris (1997) believed that male advantages on a Mathematics Scholastic Aptitude Test (SAT-M) was an indirect effect of the better mental visualization ability of boys, on average, as compared to girls. When solving certain problems it was possible to avoid a spatial approach. Evidence showed that boys as a whole depended on spatial strategies in contrast to girls who depended more on verbal strategies to solve problems. The authors concluded that it was an over-generalization to assume that none of the girls used spatial strategies and that all boys used purely spatial strategies.

Student abilities to conceptualize knowledge often leads to greater understandings (Kulm & Bussman, 1980). Spatial sense is learned primarily by young children as locations of relative position, such as over, behind, under, and beside. As children make connections to the mathematical concepts, they develop the ability to visualize changes in location or space referred to as transformations. Transformations such as slides, flips and turns shape students' thinking in formal situations as well as informal ones. Even at a young age, females perform spatial tasks less proficiently than comparable males. Females were shown to rely more heavily on manipulatives to solve problems as opposed to males who used mental representations for solving the same problems (Carr & Jessup, 1997).

While taking a broader view, Battista, Clements, Arnoff, Battista, and Borrow (1998) believed that structuring two-dimensional space was the foundation for geometric and visual thinking. "All of geometry is, in essence, a way of structuring space and studying the consequences of that structuring. We structure space when we organize it by arrays or coordinate system. We structure space when we conceptualize it in terms of specific shapes (such as lines, angles, polygons, and polyhedra)" (p.531).

Kersh (1981) stated that the school curriculum must include spatial strategies as an important contributor towards mathematical performance for males and females. The trend was toward a mathematical curriculum that incorporated spatial visualization at all grade levels (Kersh, 1981; NCTM, 2000).

The *National Council of Teachers of Mathematics Principles and Standards (NCTM, 2000)* proposed the following competencies for spatial visualization: (a) identify a three-dimensional shape from a set of two-dimensional views, (b) visualize and sketch three-dimensional shapes in two dimensions, and (c) use spatial orientation to navigate to the same point from several different starting positions. According the NCTM, (1989, 1991, 1995, 2000) students structured geometric learning as one-dimensional paths. Clements & Battista (1992) found that students followed these paths as if they were traveling along a road and had no awareness of their surroundings, as if in a tunnel. Students based three-dimensional visualization solidly on a two-dimensional foundation. The lack of a curricular structure that emphasized geometric skills hindered and possibly impeded student achievement in the subject areas where spatial visualization was essential.

Some research has indicated that gender differences exist in spatial visualization attributing these differences to brain physiology. Kitchens (1991), Kinsbourne (1982), Springer and Deutsch (1981) wrote about the left brain as mathematical and a right brain as verbal. The theory was expanded into the theory of hemispheric specialization of the brain. In general, the left hemisphere was described as specialized for analytic/logical thinking in both verbal and numerical operations. The right hemisphere, on the other hand, predominated for spatial tasks, artistic endeavor, and body image. This physiology of the brain suggested that gender differences in verbal and spatial abilities were accounted for in the ways that the functions were distributed between the cerebral hemispheres in males and females. The researchers hypothesized that both language and spatial abilities were represented more bilaterally in females than in males. Through testing, the hypothesis led to an understanding that greater lateralization of function or specialization was responsible for high spatial performance in males, while less lateralization or specialization led to better verbal performance in females.

Mitchelmore (1976) found that students' ability to visualize three-dimensional objects directly related to their ability to solve other types of geometric problems. This study connected visualization to geometry content knowledge. The researcher indicated that students who scored highly on visualization items also scored highly on general geometry items. Mitchelmore's study indicated a strong positive relationship of spatial visualization to mathematics achievement. Attempts to sequence geometry content knowledge and geometric spatial sense has been difficult since there was evidence that females and ethnic minorities learned geometry and geometric spatial sense at different rates and in different ways from White males. Mitchelmore (1976) studied Black students and observed various stages of spatial development that demonstrated a dynamic relationship in learning spatial visualization that can and does change over time and experience. Black students who participated in a training program for spatial sense improved their skills on abstract assessments. Additionally, males demonstrated a greater improvement than did females of the same ethnic population. Females and Blacks lagged behind in geometry content knowledge and spatial visualization, but skills training reduced the gap. White males, however, seemed to develop spatial ability without formal training when assessed abstractly.

Do boys and girls with discrepant or highly correlated visualization and verbal skills differ on their ability to translate symbols into a pictorial representation? Fennema and Tartre (1985) examined the phenomena and the results indicated a significant difference in gender, with the difference favoring boys. The high spatial visualization/low verbal skills students translated more symbols into pictures more completely than the low spatial visualization/high verbal skills students. Interestingly, the low spatial/high verbal girls put the least information on their paper for the translation portion than any other group, indicating that gender and spatial ability were significant factors in mathematical problem, solving. The researchers also examined whether boys and girls differed in the ability to use spatial visualization skills directly during mathematical problem solving, and found that boys were more inclined to use mental visualization and rotation than girls. A logical process was revealed that related spatial visualization skills to many important mathematical ideas as well as the ability to learn mathematics in general.

The specific purpose of this study was to determine the relationships among the factors of geometry content knowledge, spatial visualization, gender, ethnicity, and to explore qualitatively the possible explanations that led to the participants' achievement in geometry content knowledge and spatial visualization.

Methodology

The primary sample for this study consisted of 287 sixth-grade students from three public schools in a southern state in the United States. Questionnaires were administered to 296 students during spring 2000. Although questionnaires were returned from 296 participants, nine students were absent from some portion of the testing. These nine students were excluded from the study.

The demographic composition of the primary participant sample and the school district in total is presented in the Demographic Information Table (Table 1). Of the 287 participants, 54.4% were females; 81.2% were White, 15% Black, and 3.8% Other. The districts surveyed provided demographic information for the entire student population based on enrollment as of May 2000. The sample data reasonably reflected the demographics of the school districts in which the study was conducted. The overall percentage of ethnic enrollment was 76% white, 22% black, and 2% other.

INSERT TABLE 1 ABOUT HERE

All participants were administered the *Geometry Content Knowledge* (GCKT) test (Carroll, 1998). The test classified students into van Hiele levels ranging from 0-2. For a student to earn a Level 0 designation the student had to score a minimum of five questions correct out of the first seven questions. After having achieved a Level 0 designation, the student must score a minimum of six questions correct out of the next eight questions to achieve a Level 1 designation. Finally, after attaining a designation of Level 1, the student must score a minimum of seven correct out of 10 on the remaining questions to achieve a Level 2 designation. Students were placed on the most advanced consecutive level they achieved. The GCKT was unable to discern the van Hiele level for a large number of students. Level 0, the largest category achieved by 126 students in this study; 41 students attained level 1; and 11 students attained level 2 (n=287). As noted in Table 2, 38% were not classified by the test. Students on Level 0 were considered low and students on Level 2 were considered high on GCK.

INSERT TABLE 2 ABOUT HERE

Reliability for the GCKT was not presented for all levels zero through two in the literature. The published data provides a split-half reliability of .92, which was a test-retest statistic that considers the whole instrument and not the subscales

(Carroll, 1998). The reliabilities for scores in this study on all three levels were weak. The reliability of Level 2 was the strongest at .61. It also contained the greatest number of items of all three levels as shown in Table 3. The over all coefficient alpha for all items was .74.

INSERT TABLE 3 ABOUT HERE

All participants (n=287) were also administered the *Spatial Visualization* sub-test of the *Differential Aptitude Test* (Bennett, Seashore, & Wesman, 1973). Students scoring less than 20 questions correct were considered low and students scoring greater than 38 questions correct were considered high in GSV ability. The published reliability for scores on the *Spatial Visualization* sub-test was .89 (Table 3). The reliability for the scores in this sample was .93 (Table 3). The authors of the test indicated that no sub-scales existed within the 50-question test. No research to date tested the *Space Relations* portion of *the Differential Aptitude Test* for sub-scales.

Qualitative Methods

The qualitative portion sought to explore how gender or ethnic differences influenced GCK or GSV abilities. Students were selected to participate in the qualitative investigation based on three criteria: (a) field notes, (b) student responses to biographical data, and (c) test scores. First, the researcher wrote field notes about the students to whom he administered each of the tests. As students completed each test, they were asked to respond to each of the biographical questions listed in Table 4. First, written responses from students were read and compared to the field notes taken during testing sessions. Any comments that differentiated any student from the others or promised unique insights were identified for later review in conjunction with test analysis. In a few cases some students chose not to respond to the questions and therefore, those students were considered based solely on available qualitative and quantitative data. Participants were then grouped based on GCK and GSV test scores into high and low groups as shown in Table 5.

INSERT TABLE 4 ABOUT HERE

INSERT TABLE 5 ABOUT HERE

The qualitative interview portion included 11 students (Table 6). Students who promised interesting insights into the phenomena were selected and a widely diversified group emerged representing each of the possible quantitative categories. Representatives from each of the ethnic groups were present. Eleven students in all were interviewed using the guiding interview questions shown in Table 7 and asked to solve a sample spatial visualization question. The interviews were audio recorded and field notes were written.

INSERT TABLE 6 ABOUT HERE

INSERT TABLE 7 ABOUT HERE

The first step in the process of determining patterns and themes was to transcribe and code the data. The data were coded by creating a table and copying and pasting common student comments from the interviews into the same cells. This method allowed the same information to be coded into multiple cells as necessary. Once all the interviews were coded, a basic descriptor of that particular column was attached, for example, physical play. Second, telephone interviews using the same questions (Table 7) with parents were coded in much the same way using the same general categories that emerged from the student responses. Last, a second, follow-up interview with the parent and child was used to confirm the findings and ensure the accuracy of their statements. Any new information was updated directly to the table. Once the table was complete, the richness of the study became evident.

Results

While some descriptive statistics are helpful, Table 8 lists mean scores and standard deviations for the scores on both measures.

INSERT TABLE 8 ABOUT HERE

In determining if there was a difference in the mean geometry content knowledge (GCK) scores between gender and the three ethnic groups of White, Black, and Other regression analyses were run using SPSS version 9.0. A statistically significant difference ($p<.01$) was found between the ethnic groups for the criterion variable of geometry content knowledge (Table 9). Multiple comparisons between the three ethnic groups were made using Tukey's HSD test (Table 10). The mean of the Black students (11.00) as compared to the mean of White students (14.10) was statistically significant at the $p < .01$ level with the mean of the White students being greater (Table 10). The mean of the Black students (11.00) as compared to the means of the "Other" students (14.75) was statistically significant at the $p <. 01$ level with the mean of the "Other" students being greater. The mean of the White students (14.10) as compared to the means of the "Other" students (14.75) was not statistically significant at the .05 level. No statistically significant differences between males and females in geometry content knowledge were found for the regression analysis. The results suggested that no important gender differences in GCK existed.

INSERT TABLE 9 ABOUT HERE

INSERT TABLE 10 ABOUT HERE

In determining if there was a difference in mean geometric spatial visualization scores between the three ethnic groups a regression analysis was run with the results listed in Table 11. The results indicated that there was no difference in the mean geometric spatial visualization scores between ethnic groups. Race does not appear to be important when considering GSV scores. The results also suggested that no statistically significant differences were found between males and females across the regression analyses for geometric spatial visualization as shown in Table 11.

INSERT TABLE 11 ABOUT HERE

Qualitative Themes and Patterns

Many insights were gained throughout this course of study and several meta-patterns and meta-themes evolved. Student responses varied and differences emerged in parenting and "parent as first teacher" became evident. In response to the first question regarding how the indirect learning experiences differed when comparing high and low achievers responses varied. The answer to this question ranged widely as much from achievement as ethnicity. Fros, a black male with a high GSV score, remembered learning how to do things as a result his mother showing him and not by being told. On the other hand, Bubbles, a high achieving (in both tests) white female, told about her interest in games and building using Lincoln Logs. She said, " . . . It (the book that accompanied her Lincoln Log set) showed me how to build houses and stuff from looking at the pictures. . . I built houses . . . and I did not forget the windows." Lower achievers in GSV were more likely to have remembered playing with dolls or teddy bears. Annie explained, " When I was little I used to have a teddy bear that I took everywhere but my mom said it was time to grow up and that teddy had to move out."

Patterns and themes became evident as the data was analyzed. Along racial lines, Black students expressed more interest in "doing" things. Tom, in his biographical data said, " I really like making stuff. . . .we hardly ever make anything in school." The same student, identified as learning disabled, in his interview referred to the GSV test and said, "It's like stuck in my head 'cause you know, it was complicated." Tom expressed interest in things that were complicated and had the largest range of scores between the geometry tests for all 287 participants. His GSV score was 40 and his GCK raw score was only 9, too low to even be placed on one of the van Hiele Levels. Tom, like other interviewees, could not remember having been taught spatial visualization, three-dimensional objects, or asked to compare views of building blocks but he seemed to excel at GSV. Fros another black male demonstrated a strong ability for GSV (van Hiele Level 0). He remembered, " My favorite test was the one where you matched the open picture with the folded one." Fros was referring to the GSV test. Once again his GSV test score placed him in the high group whereas his GCK score placed him in the low category. When the investigator asked Fros about having been taught GSV in school he replied, " No! It would have been too difficult for them [meaning teachers]." Fros also took great pleasure in detailing how he "saw" the answer, " . . . this is how I saw it, with the square being here [indicating the position on the cut-out cube] and the stripes are on the bottom, and on the top." Finally, in response to the question about what activity outside of school might have helped him to solve spatial visualization problems he related this story," My mother used to teach me to do things by showing me. Like making my bed. It's kind of a cube and you have to cover it with the spread. She used to talk about making sure all the sides were even and that not too much of the spread was on one side. You know all of the sides are the same only the tops and bottoms are different from the sides." He also said that he hated the GCK test because, " . . .[I] just memorize the stuff . . . I know my teachers taught it but I didn't learn it. "Spooky, a bi-racial male, Black and White, indicated that he remembered playing with blocks when he was in the three to five year old age range. In the age range of six to nine though, he mostly remembers playing outside games like football and basketball, " . . . you know big kid games." Spooky expressed little interest in board games or other toys.

When comparing students based on race, White students' responses were more varied. The white students often remembered playing with board games, dolls, blocks, or puppets. Steve, a white male, preferred the GCK test and actually performed well on both. He related a story to me about learning spatial visualization in third grade, " I remember folding things up and seeing what they were going to look like completed." Upon further questioning in the telephone interview, Steve remembered that he just remembered folding boxes and they were used as dice to play a game. During the parent and child interview the parent stated, " . . . all that folding was just a waste of time when he could have been working on his fractions or something like that."

Blue Eyes and her mom related this story, "She [Blue Eyes] used to play mostly with dolls. She liked to take parts off of one doll and put them on another." Similarly, Elizabeth remembered, " Well....Let's see, well, I got these little baby dolls for Christmas and played with them. I played with those little puppets that they would sell at Burger King or McDonalds and get those, and I played with the little baby toys that I got when I was a baby." When considering participant responses along racial lines it was obvious that Black students differed greatly in their choice of play and activities. In general, Blacks preferred gross motor skills as opposed to Whites.

The second theme from the responses to question one that emerged was related to gender. The highest score on the GSV test was held by two females one

White and one Hispanic, Bubbles and Taylor. Bubbles exhibited many "Tomboyish" characteristics by her own admission. She liked to play Boggle, claimed to have had a whole bunch of dolls, and liked building with Lincoln Logs. She enjoyed playing outside, climbing trees, and playing sports like baseball and football with boys. During her interview she said, " It [Lincoln Logs] showed you how to build houses. I built the houses and stuff." Taylor, almost the opposite of Bubbles, enjoyed quiet time and played the Spanish version of Monopoly. She was not allowed to go outside and play and "climbing and playing games with boys was not allowed." When asked about doing any spatial activities in class, Taylor remembered, "We did flip, slides, and turns with shapes. You have to imagine what the shape would look like after you turn it around or flip it over." Bubbles claimed interest in the more difficult board games like Trivial Pursuit and Scrabble usually playing and interacting with her much older sister and parents. In this lies the commonality between the Bubbles and Taylor. Both the girls spent more time with older relatives and parents in both homework and play than did other students who scored lower on GSV. In fact, both girls related that Monopoly probably helped them learn to picture what they were doing. During the parent interview, with Bubbles and Taylor, it was revealed that when the students were speaking about picturing what they were doing, they actually meant reasoning and thinking the situation through from different perspectives. For example, as the Monopoly piece goes around the board it changes location and they both recalled picturing the board and position of the pieces on the board from different perspectives figuring out the number of spaces. Obviously, the board is rectangular what they were probably doing was reasoning out how many spaces they need to move in order to land on what they wanted or to avoid someone else's property.

Generally, the White male participants recalled combinations of events. Steve responded that he did recall doing something he considered spatial visualization in school. He said, "Um..Yes Sir, I think, maybe three years ago." These recollections would have put him in third grade. When questioned further, Steve responded, " I'm pretty sure it was just [making] boxes [cubes]." Steve also commented more about playing on, around or in something, he said, "My very first toy was like a plastic tree house that you could climb in and slide down." These experiences were shared by Flame. He remembered one of his teachers doing a spatial visualization activity, " For art we made stuff like fish and stars and frogs out of paper. We also made some shapes like boxes and pyramids." He echoed the idea of climbing in and around objects as play things. He told me, " . . . sometimes I got into the kitchen and took the pots and pans out of the closet. I liked to make noise with them. I liked getting in the closet and climbing on the chairs and dropping the pans on the floor. Ryan, also a White male, recalled," We made cubes like dice." and for what he played with he told it like this, " I played with cars and things you push around like wagons. Fisher toys! We would play games like hide and go seek." During hide and go seek, one gets into, crawls under, climbs onto objects all similar to the things mentioned by the other White males. None of the White males indicated that they learned, were explained, or shown by parents how to make the bed or do any other household chore. They remember just being asked to "straighten your room", or "take out the garbage".

Summary

As mathematics becomes better understood as a plural noun, and interpreted as reflecting various domains that sometimes require vastly different thinking processes, new results will continue to emerge from studies exploring mathematics as multi-dimensional.

Gender , as opposed to some current literature (Battista, 1990; Casey, Nuttall, & Pezaris, 1997; Casey, Nuttall, Pezaris, & Benbow, 1995; Hedges & Nowell, 1995; Hyde, Fennema, & Lamon, 1990; Lumis & Stevenson, 1990; Terwilliger & Titus, 1995), was not meaningful in accounting for variance explained. Gender was not indicated as having an effect on either geometric content knowledge or geometric spatial visualization. The evidence seemed to indicate that regardless of performance White students preferred the GCK test and Black students preferred the GSV test and that coincides with the results of the regression analyses.

There was a statistically significant difference between ethnic groups on geometry content knowledge. The differences exist in the direction that both the means of the Whites and Others were greater than that of Blacks. No significant differences exist between Whites and Others. Interestingly, there were no differences in ethnicity on spatial visualization, in fact the means of Black students were slightly higher that that of the White students. What accounts for the difference in performance of Black students on the two measures? The qualitative results suggest that Black students may exhibit more spatial abilities as a result of the type and quality of the home interactions with parents. All of the Black students recalled their parents showing them how to do something and several of the Black parents checked the researchers understanding by asking " . . . do you see what I mean?" even though the conversation was taking place over the telephone.

In part, the purpose of the qualitative portion of this study was to identify and explain performance on geometry content knowledge and geometric spatial visualization. The information-rich emergent data provided themes and patterns. Among those themes, types of play, gross motor versus fine motor skills, parenting talk to their children, and a reported lack of geometry content and spatial visualization taught in the schools was cited by students as reasons for their perceived performance on the two measures.

Essentially, do various cultures have advantages when encountering some types of mathematical problems? If there are advantages in some areas, spatial visualization being one, what are the implications for learning other areas of mathematics taught through a spatial-visual approach? Many researchers have identified various differences in gender, or attitude but can the implications actually be positive in understanding how particular groups of students learn and matching those talents to the proposed learning tasks. It is this very idea that student strengths be identified and those strengths be utilized to enhance and improve instruction.

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Table 1

Demographic Information

Total Sample Demographic Information									
A					B				
Black	White	Other	Female	Male	Black	White	Other	Female	Male
19	44	2	38	27	24	189	9	118	104
30%	67%	3%	58%	42%	11%	85%	4%	53%	47%

Total School District Demographic Information									
A					B				
Black	White	Other	Female	Male	Black	White	Other	Female	Male
920	1535	15	1359	1111	441	3153	82	1985	1691
37%	62%	1%	55%	45%	12%	86%	2%	54%	46%

Table 2

Students Scoring in each of the van Hiele Levels on GCK

n = 287	Level 0	Level 1	Level 2	Not Placed
Percentage	44%	14%	4%	38%
Number	126	41	11	109

* Level 0 is lowest

Table 3

Reliability Scores for All Instruments

Test	Subscales	Sample Alpha	Items	Published Alpha
GCK test	Level 0	.30	1-7	NA
	Level 1	.44	8-15	NA
	Level 2	.61	17-26	NA
	Overall	.74	1-26	.92*
Space Relations	Overall	.93	1-50	.89

*Test-Retest reliability

Table 4

Student Free Response Questions /Prompts for Biographical Data

Write in paragraph form. Tell me anything you would like me to know about yourself.
Tell me about what you like and dislike about school.
Write about your favorite activity, pet, and game.
Explain why you wanted to participate in this study.
Describe one person you know. They do not have to be either a friend or an enemy and only use appropriate school language.

Table 5

Student Grouping Chart

Grouping I & 2	Grouping 3 & 4
High GCK and High GSV	Low GCK and High GSV
High GCK and Low GSV	Low GCK and Low GSV

Table 6

Qualitative Participant Demographics

Pseudonym	Gender	Race	GSV Raw Score	van Hiele Level
Elizabeth	Female	W	39	0
Ryan	Male	W	39	2
Flame	Male	W	39	1
Fros	Male	B	45	0
Bubbles	Female	W	48	2
Taylor	Female	H	48	0
Spooky	Male	B/W	43	0
Tom	Male	B	40	NP
Blue Eyes	Female	W	40	1
Steve	Male	W	43	1
Annie	Female	W	35	1

W= White, B= Black non-Hispanic, H= Hispanic, B/W= Bi-racial Black and White
NP= Not placed on Van Hiele Level

Table 7

Qualitative Research Questions

Qualitative research question:	Student version of the qualitative research question:
How does the reported experiential or indirect learning of high achievers differ from that of low achievers concerning spatial visual sense?	What do you think you did when you were not in school that helped you learn about solving these types (spatial visualization) of problems? Can you remember when you were very little? What types of toys did you play with or what types of games did you play?
What are the differences in the educational experiences of high achievers and low achievers in spatial visual sense?	Do you remember anything that you or your teacher did in school that may have helped you to solve these (spatial visualization) types of problems?
What are the differences between the reported learning methods and exposure of high achievers and low achievers in spatial visual sense?	What do you think helped you the most in solving these (spatial visual) types of problems? Did any of your teachers teach you about these (spatial visualization) problems?

Table 8

Test Means and Standard Deviations for Sample

			GCK		GSV	
Gender	Ethnicity	n	$\bar{X}$	SD	$\bar{X}$	SD
	Black	17	10.8	3.84	22.7	9.42
Male	White	107	14.2	5.23	25.6	10.74
	Other	7	12.0	3.37	23.4	9.05
TOTAL		131	16.6	5.11	25.1	10.48
	Black	26	11.2	3.20	20.6	7.61
Female	White	126	14.0	4.27	24.6	9.62
	Other	4	17.5	8.43	28.5	15.20
TOTAL		156	13.6	4.38	24.0	9.55

Table 9

Results of Regression Test GCK as the Dependent

Source	df	MS	F	p	R^2_{Change}
Race	2	164.6	7.7	.001	.052
Gender	1	.353	.017	.898	.000
Residual	283	21.3			

Table 10

Multiple Comparison - Tukey's HSD Test

Comparison	Difference	P	HSD Calculated
Black -vs- White	3.1	<.05	2.95
Black -vs- Other	3.75	<.05	
Other -vs- White	.65	NS	

Table 11

Results of Regression Test GSV as the Dependent

Source	df	MS	F	p	R^2_{Change}
Race	2	228.8	2.3	.101	.016
Gender	1	65.4	.67	.416	.002
Residual	283	98.8			

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