Investigating Spatial Visualization van Hiele Levels and Early Experiences

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Abstract

Van Hiele (1957) determined that learning geometry is experiential. In other words, it is not strictly developmental; it depends on how one engages with shapes and their relationships. Earlier studies of spatial visualization have posited that males are more spatially visual than females (Fennema, 1977). However, the literature does not take into account the different environments in which males and females grow up and their variation in childhood experiences. This paper investigates the possible relationship between early experiences, such as playing video games or sports, and a person's spatial visualization level.

Introduction

Spatial visualization is one's ability to mentally picture and manipulate two-dimensional and three-dimensional objects in a plane. Thus the ability to spatially visualize is important in learning geometry and mathematics in general. For instance, in a geometry class, a student may be asked to list the cross sections of a right circular cylinder on a test. First, the student would need to visualize a right circular cylinder. Then, imagine slicing the solid along the vertical and horizontal axes and diagonals to determine the cross sections. Visualizing the motion of slicing and what the resulting cross section looks like can be difficult, especially in a testing environment. While it's possible to rote memorize the cross sections of a right circular cylinder and other three-dimensional solids, if a student is given a nonstandard solid, rote memorization will prove ineffective in solving the problem. Therefore, being spatially visual is necessary to be successful in a geometry class. However, not everyone has the same prowess in spatial visualization.

Van Hiele (1957) determined that learning geometry was experiential rather than developmental, implying that engaging with shapes and their relationships affected one's learning more so than their biological development. Studies of spatial visualization ability have historically implied that males perform better on these tasks than females. Other studies have tried to pinpoint the exact age at which this sex difference in spatial visualization first appears. These differences are not attributed to biology. However, none of the previous literature directly addresses the differing experiences that boys and girls have in their early childhoods that may contribute to the difference in spatial visualization ability.

The purpose of this research is to investigate connections between early experiences, specifically playing video games and sports, and one's spatial visualization ability using the van Hiele levels as a framework. Specifically the research questions are as follows:

1. Are early experiences correlated to higher spatial visualization van Hiele levels?
    a. Does playing video games positively affect spatial visualization ability?
    b. Does playing sports positively affect spatial visualization ability?
    c. Does the type of geometry classroom experience positively affect spatial visualization ability?

One study has researched the effect of playing video games on spatial visualization ability. The researchers only looked at the immediate effect of playing video games based on the success on a test of spatial visualization ability, and the study revealed that females benefitted, even scored as high as males, from video game experience (Gagnon, 1985). There have been no studies that have analyzed the effect of playing sports. There are not copious amounts of research on the possible factors that affect spatial visualization ability, which makes this research novel and further motivates the need for this study.

I currently do not consider myself to be a very spatially visual person. As a future educator, I will have students that have not developed very sophisticated spatial visualization abilities. Therefore, researching what experiences positively affect spatial visualization ability will influence the way I teach geometry concepts. It is important that students also learn to develop this skill. If playing video games or sports is shown to be correlated to higher spatial visualization ability levels, then perhaps students need to be playing sports or video games once a week instead of sitting behind desks and copying formulas. Since the previous research has indicated that males are better at being spatially visual than females, if my current study shows that certain experiences lead to higher levels, then that may encourage more females to pursue geometric experiences and careers in STEM fields. If there is indeed a significant theme or connection to certain experiences and high van Hiele levels of spatial visualization, this research can influence the kinds of activities that I, as a future mathematics educator, and other teachers can engage their students in to increase their spatial visualization ability.

Literature Review

Studies of students' comprehension and learning of geometric concepts have necessarily lead researchers to assess students' mental operations such as spatial visualization (Battista and Clements, 1996). While Battista and Clements did not directly address spatial visualization, they explore "…in depth general cognitive operations such as coordination, integration, and 'structuring' as they are manifested in the spatial context" (1996, p. 260). An activity used in their study to evaluate students' understanding was constructing an array of cubes given the orthogonal front, top, and right views. From this activity they defined coordination as the students' recognition of "how these views are spatially interrelated" (p. 284), integration as the ability to "construct a single coherent mental model of the object that possesses these views" (p. 285), and spatial structuring as "the mental act of constructing an organization or form for an object or set of objects" (p. 282). These three mental operations can be considered under the umbrella of the general definition of spatial visualization.

There have been studies strictly devoted to spatial visualization; one of the most prominent researchers in the field was Elizabeth Fennema. Studies of spatial visualization ability had uncovered differences between males and females, and this is primarily what Fennema studied. In their study, Fennema and Sherman (1977) investigated the potential variables that contribute to this sex difference as well as "the empirical relationship between spatial visualization and mathematics achievement and the relationship between visualization and any sex-related differences in mathematics achievement" (p. 28). The affective variables that were considered, however, were mostly related to attitude, perception, and confidence in mathematics of high school boys and girls. Through their results they concluded that when considering males and females with similar mathematical backgrounds the difference in spatial visualization ability and mathematical achievement between the sexes was not as significant as initially thought, and "that many females have as much mathematical potential as do many males" (p. 37).

In a later study, Fennema and Sherman (1978) explored in more depth the affective variables from the previous study with middle school boys and girls. Fennema and Sherman wrote that "[girls] perceived their teachers as being significantly less positive toward them as learners of mathematics," (p. 198), while "males were significantly more confident of their ability to learn mathematics than were females and that males stereotyped mathematics as a male domain at higher levels than did females" (p. 194). From the results of the study, Fennema and Sherman posit that claims of sex-related "differences" from other studies may not have accurately accounted for confounding variables such as mathematical background and that the difference in attitudes and perceptions of males and females in mathematics may be more likely to contribute to these differences in mathematics achievement more so than biology.

Nearly ten years later in 1985, Fennema and Tartre revisited spatial visualization for the purposes of determining if girls and boys with varying spatial visualization ability and verbal skills would differ in areas such as problems solving and the use of spatial visualization in that process, ability to verbalize relevant information, and the ability to accurately create and use pictorial representations. While the high spatial/low verbal groups could accurately create and use pictorial representations better than the low spatial/high verbal groups, who were able to more accurately verbalize relevant information, there was not a significant difference in the high spatial/low verbal groups from the low spatial/high verbal groups in the ability to problem solve.

This is supported by Battista who wrote “the results [of the study] indicate the spatial visualization and logical reasoning were important factors in geometry achievement and geometric problem solving for both males and females” (p.56). However, “[the] results suggest that male and female students differed in spatial visualization and their performance in high school geometry but not in their use of geometric problem solving strategies” (p. 57).

While many of these researchers have attempted to discover the extent of this sex difference in spatial visualization ability, Johnson and Meade (1987) investigated around what age these differences may occur. By using paper and pencil tests to evaluate spatial visualization, which were also proven to be effective in measuring spatial ability, Johnson and Meade discovered that “a male advantage in spatial ability exists at least as early as the fourth grade (age 10) over a wide range of paper and pencil measures” (p. 735).

Despite the studies of spatial visualization that examined this sex difference, Fennema and Tarte concluded that “the use of spatial visualization skills may indeed help explain sex-related differences in mathematics, but one must never say, think, or most of all, believe that all girls are less able than all boys to use their spatial visualization skills appropriately in mathematics” (p. 205).

Battista and Clements, in their discussion of students’ procedures for the orthogonal views to a three-dimensional cubic array task, outlined the characteristics of different levels of sophistication in students’ solution attempts. “Some students made one building for each view” (p. 286). “Other students recognized that coordination was needed but were unable to accomplish it” (p. 286). Some students stumbled upon the solution through guess and check. More sophisticated mental processes included reflection and prediction of effects before actual movements and “at the highest level of sophistication [students] truly integrated the information given in the three views" (p. 286). These characterizations of solution attempts are similar to the organization and purpose of the van Hiele levels.

Peter van Hiele (1957) outlined four levels of geometric thought and stated that "one can probably distinguish five levels of thought in geometry" (p. 62). These levels were based on the idea that teachers and students in a geometry class think on different levels which henceforth explains the miscommunication between teacher and student and subsequent lack of understanding by the students. The five levels are described as follows:

Level 0:

- "Figures are judged by their appearance" (p. 62).

Level 1:

- "The figures are bearers of their properties" (p. 62).

Level 2:

- "Properties are ordered" (p. 62).

Level 3:

- "Thinking is concerned with the meaning of deduction, with the converse of a theorem, with axioms, with necessary and sufficient conditions" (p. 62).

Level 4:

- Where axiom based geometries are studied and understood abstractly without concrete models (Burger and Shaughnessy, 1986, Breyfogle and Lynch, 2010).

An interesting property van Hiele gives his levels is that "the maturation must be considered above all as a process of apprenticeship and not as a ripening of a biological sort" (p. 63). This process of apprenticeship van Hiele describes in five phases: inquiry, direct orientation, explicitation, free orientation, and integration. Since their introduction in 1957 the van Hiele levels have engendered many studies into their relevance, application, and adaptations to other concepts in geometry.

Burger and Shaughnessy in their 1986 study "Characterizing the van Hiele levels of Development in Geometry" researched three questions:

1) Are the van Hiele levels useful for describing a student's thought process
2) Can the levels be characterized by student behavior
3) Is an interview sufficient enough to reveal a student's predominant van Hiele level?

All these questions were answered in the affirmative. The van Hiele levels were characterized by student behavior and referred to as level indicators. For example a level 1 indicator was "sorting by single attributes, such as properties of sides, while neglecting angles, symmetry, and so forth" (p. 44). The interview allowed the researcher "to probe further or follow up on any response" (p. 33) after a participant completed the task. "The success of the structured interview, using a specific script as a basis, enabled the reviewers to compare many students' responses to the same tasks" (p. 47).

Mayberry conducted a similar study of the characteristics of the levels such as the hierarchal structuring in her 1983 study. Two hypotheses were tested: 1) A student can answer questions at or below their level across geometric domains, 2) A student will be at the same van Hiele level across all geometric domains (Mayberry, 1983). The study revealed that students have different van Hiele levels for different geometric domains. This generates the question of on what level does a student operate if he or she appears to be between levels.

The way in which van Hiele outlined the process for attainment of a new level only describes the process, but Gutierrez, Jaime, and Fortuny (1991) investigated the question of transition between levels. The study took the five step process of acquisition outlined by van

Hiele, quantified it on a scale from 0 to 100, and then broke it into five periods: no, low, intermediate, high, and complete acquisition. Using the quality and correctness of the participants' answers to rate them on the acquisition scale, the study's data implied that "not all students used a single level of reasoning, but some of them used several levels at the same time, probably depending on the difficulty of the problem" (p. 250).

While the original five van Hiele levels were outlined for two-dimensional shapes, studies like Gutierrez's (1992) attempted to "give some ideas about some possible characteristics of the van Hiele levels in the topic of spatial visualization" (p. 34), though more specifically in three-dimensional space. The descriptions are as follows:

Level 0:

- Students cannot visualize a solid or movement of a solid in a nonvisible position.
- Students move a solid by guessing.

Level 1:

- Students can visualize simple movements to and from nonvisible positions.
- Students move a solid based on its current and final positions.

Level 2:

- Students can visualize and pre-plan movements of solids to and from nonvisible positions.

Level 3:

- Students pre-plan movements of solids based on their analysis of the solid and make correct and appropriate movements.

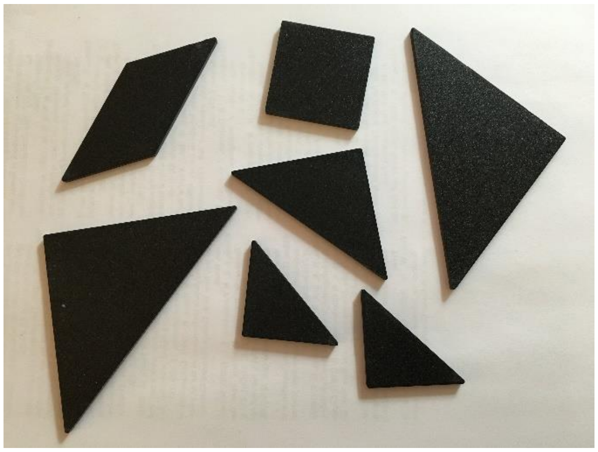
The fourth level was not described Like Battista and Clements, Gutierrez characterized this proposed adaptation of the van Hiele levels based off of observation of student behavior.

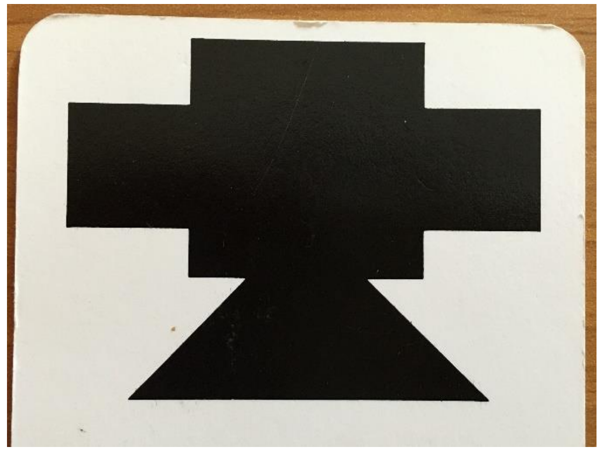
Methods

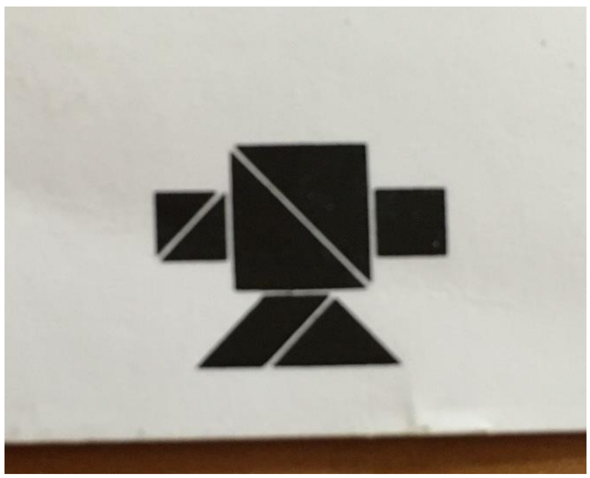
In order to analyze the effects of playing video games or sports on spatial visualization ability, the goal for the sample was to have participants from three intentionally selected groups: athletes, targeted video game players, and preservice teachers from Georgia College. GC athletes and video game players were targeted groups because of their continued pursuit of their pass times beyond childhood which speaks to the more serious dedication they may have had in childhood compared to someone who only played sports or video games casually. The hypothesis was that video game players and college athletes would have higher spatial visualization van Hiele levels and that sex differences identified in earlier studies might not be explained by biology, but rather by the different early experiences that boys and girls, stereotypically, used to experience. This also parallels van Hiele's statement that progression through the geometrical levels is experiential.

There were only forty-seven participants in the sample, and only 10 were males. Three participants were targeted video game players at GC, and all three were male. Three participants were GC athletes, two of which were male. Six of the ten males were math majors; one was a mathematics professor. There were eight math majors in total. This sample lacked diversity and equal sampling of males and females.

Participants were asked to complete three tasks: two geometric activities and a survey. The first of these tasks was a tangram activity. Provided the seven tangrams, participants were asked to construct the figure shown without overlapping or stacking the tangrams.



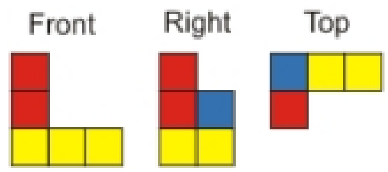


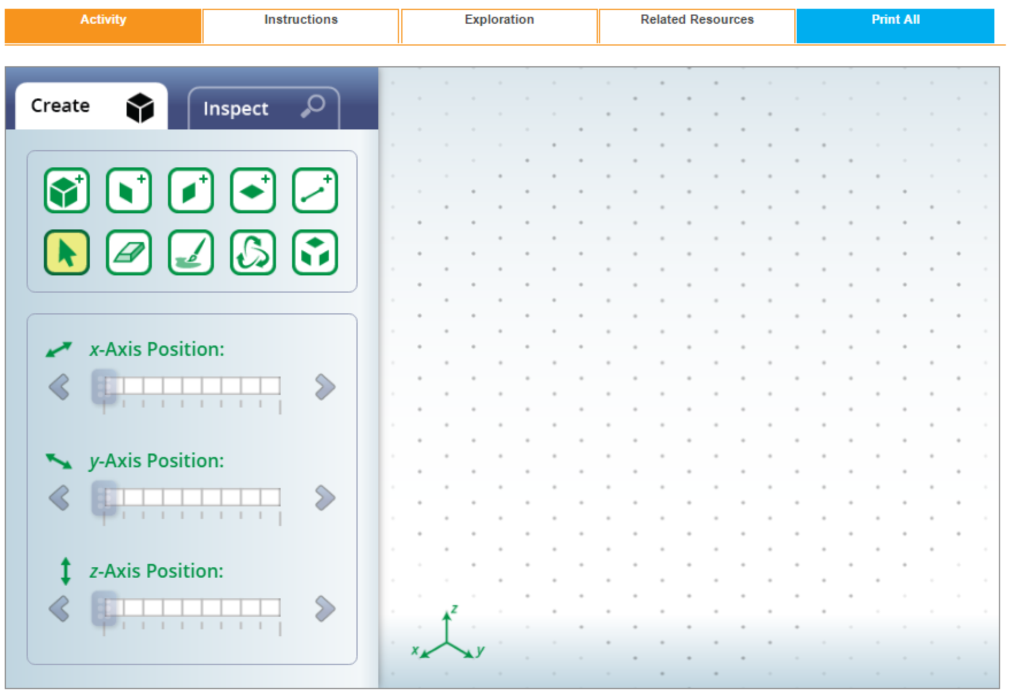


Participants were timed, but were given an unlimited amount of time to complete the activity. The answer, a scaled down image with the tangrams outlined, was provided to participants who decided they were unable to complete the activity. It is important to note that some participants gave up rather quickly, while others gave up after a sufficiently long time with the help of prodding and prompting questions. An example of a prod used for the tangram activity is: "if what you are doing isn't working, then maybe you should try something else."

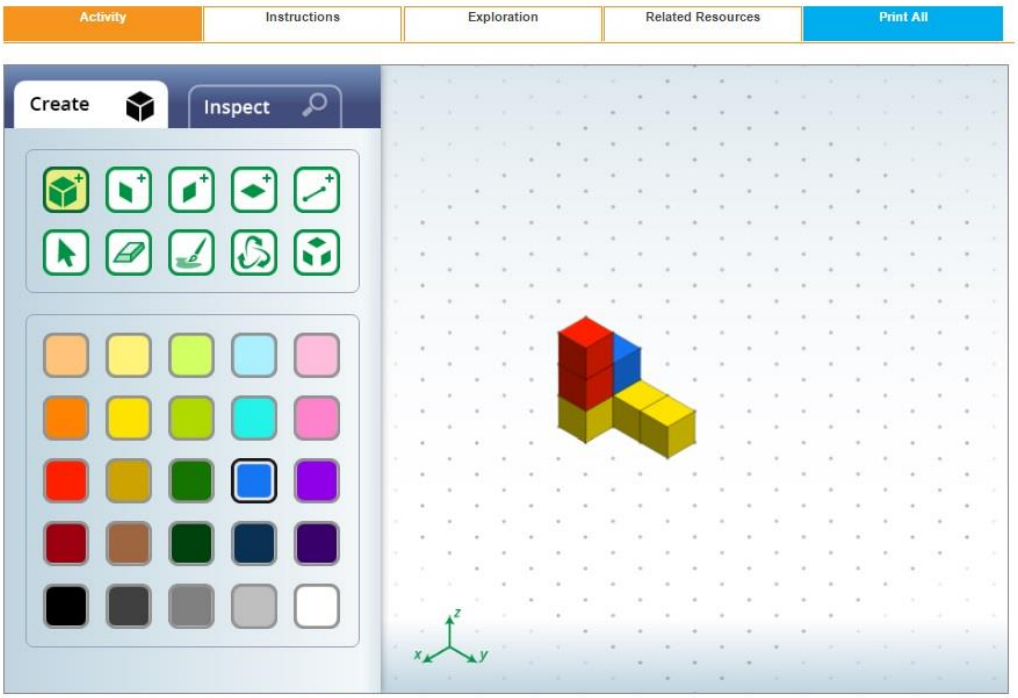
This task evaluated the participant's knowledge of transformations, composition, and decomposition of shapes.

The second task was an online activity from the NCTM illuminations website, www.illuminations.nctm.org, called the isometric drawing tool, which will henceforth be referred to as IDT. Participants were given three orthogonal views, front, right, and top, of a three-dimensional figure, and were asked to construct the three-dimensional figure with exactly seven cubes correctly colored on the computer. Participants were also given seven physical cubes to manipulate. As with the tangram activity, participants were timed, but given an unlimited





amount of time to complete the activity. Unlike the tangram activity, participants could not give up and look at the answer. Participants were asked prodding and prompting questions until the correct figure was constructed on the computer. An example of a prompt used for the IDT is "What can you change so that one view changes, but the others remain the same?" The answer is shown below.



This task evaluated a participant's understanding of the relationship between two-dimensional views and three-dimensional objects.

The last of the tasks was a survey that asked the participants about their video games, sports, and geometry classroom experiences. Since the study investigated early experiences, participants were asked to fill out the survey based on their kindergarten through twelfth grade experience. Participants were asked to indicate the types of video games or sports they played, how many hours a week they played, the number of years they played, and at what age they began playing. Participants marked on a scale from lecture style to hands-on to indicate what best described their geometry classroom experience and further explained what types of geometric experiences they had in learning geometry. Refer to Appendix A for complete survey.

Van Hiele levels were assigned for both of the activities. The van Hiele levels assigned for the tangrams used the van Hiele levels as a framework, and the van Hiele levels assigned for the IDT used Gutierrez's (1992) adaptation of the van Hiele levels outlined in his study. Fieldnotes based on the participant's process for each of the activities were used to evaluate which level a participant exhibited. The completion times for the activities were considered, but were not the most important factor. While the 0-100 scale for acquisition created by Gutierrez, Jaime and Fortuny was not used, half levels were assigned to participants who displayed characteristics of two consecutive levels but did not have all the characteristics of the higher level.

For the tangram activity, no level higher than two was distinguished. The following is a characterization of the van Hiele levels.

Level 0:

- Could not complete the activity without looking at the answer.
- Moved tangrams randomly without making connections.

Level 1:

- Could make connections with the triangles and squares.
- Moved parallelogram randomly to make connections.
- Prodding from investigator was necessary for completion.

Level 1.5:

- Made more connections with all tangrams.
- Thought about the effect of moving a tangram before physically moving it.
- Prodding was only sometimes needed for completion.

Level 2:

- Able to pre-plan movements of tangrams.
- Made accurate and appropriate connections for completion.
- Constructed the correct figure with little to no prodding.

These characterizations were based off of the field notes and observations of the participants' processes.

All five van Hiele levels were discernable for the IDT. The following is a characterization of the van Hiele levels.

Level 0:

- Moved blocks by guessing.
- Could not correctly build nor incorporate views onto computer or with physical blocks.
- Prompting was necessary for completion.

Level 1:

- Could visualize simple movements, but mainly moved by guess.
- Often built one view correctly on the computer or with the physical blocks if used.
- Could not easily incorporate or build other views to complete the figure.
- Perspectives on the computer were not seen correctly
- Prompting was frequently necessary for completion.

Level 1.5:

- Able to visualize movement of blocks to visible positions, but struggled to visualize how the views would change.
- Could usually incorporate and build two views on the computer or with the physical blocks if used.
- Often confused perspectives on the computer.
- Prompting was frequently necessary for completion.

Level 2:

- Able to visualize movement of blocks to visible and sometimes nonvisible positions.

- Could accurately incorporate and build two views on the computer or with the physical blocks if used.
- Often confused perspectives on the computer with the perspectives of their physical figure if constructed.
- Prompting was often necessary for completion.

Level 2.5:

- Could anticipate changes in views before moving blocks to visible positions.
- Could sometimes accurately incorporate at least two views.
- Sometimes confused perspectives on the computer with the perspectives of their physical figure if constructed.
- Prompting was often necessary for completion.

Level 3:

- Able to visualize movements of blocks and how the views change before moving the blocks to visible and nonvisible positions.
- Usually incorporated and built all three views correctly.
- Sometimes confused perspectives on the computer with the perspectives of their physical figure if constructed.
- Prompting was sometimes necessary for completion.

Level 3.5:

- Able to visualize movements of blocks and how the views change before moving the blocks to visible and nonvisible positions.
- Able to incorporate and build all three views correctly.

- Rarely confused perspectives on the computer with the perspectives of their physical figures if constructed.
- Could correct figure deliberately rather than by guess.
- Prompting was rarely necessary for completion.

Level 4:

- Able to mentally visualize, preplan, and construct the correct figure on the computer and with the physical blocks if used with little to no error.
- Could correctly incorporate and build all three views from the correct perspectives.
- Did not have trouble building the physical figure and easily transferred it to the computer.

Again, these characterizations of the levels were based off of field notes and observations of the participants' processes.

Findings

The statistical software package, SPSS was used to run two-way ANOVAs comparing the four response variables: tangram van Hiele level, IDT van Hiele level, tangram time, and IDT time with the explanatory variable gender and either: video games, ball sports, math major, or geometric experience. All independent variables were quantified. For gender, 0 was assigned to females and 1 assigned to males. The initial research questions focused on video games, sports, and geometry classroom experience. However, because so many males were math majors it was intriguing to look at how being a math major affected the van Hiele levels for the activities. For the sake of organization, the data analysis will be divided into the four independent variables: video games, ball sports, geometry classroom experience, and math major.

Of the 47 participants, six did not play video games, and it is important to note that all six were females. The two-way ANOVAs were performed for the four response variables, the explanatory variables were gender and video games. The number 0 was assigned to those who did not play video games, and 1 was assigned to those who did play video games. The two-way ANOVA calculated a 95% confidence interval. Only two of the four ANOVAs produced p-values less than .05 indicating significance: IDT time and IDT van Hiele level. The tangram activity did not yield any significant results.

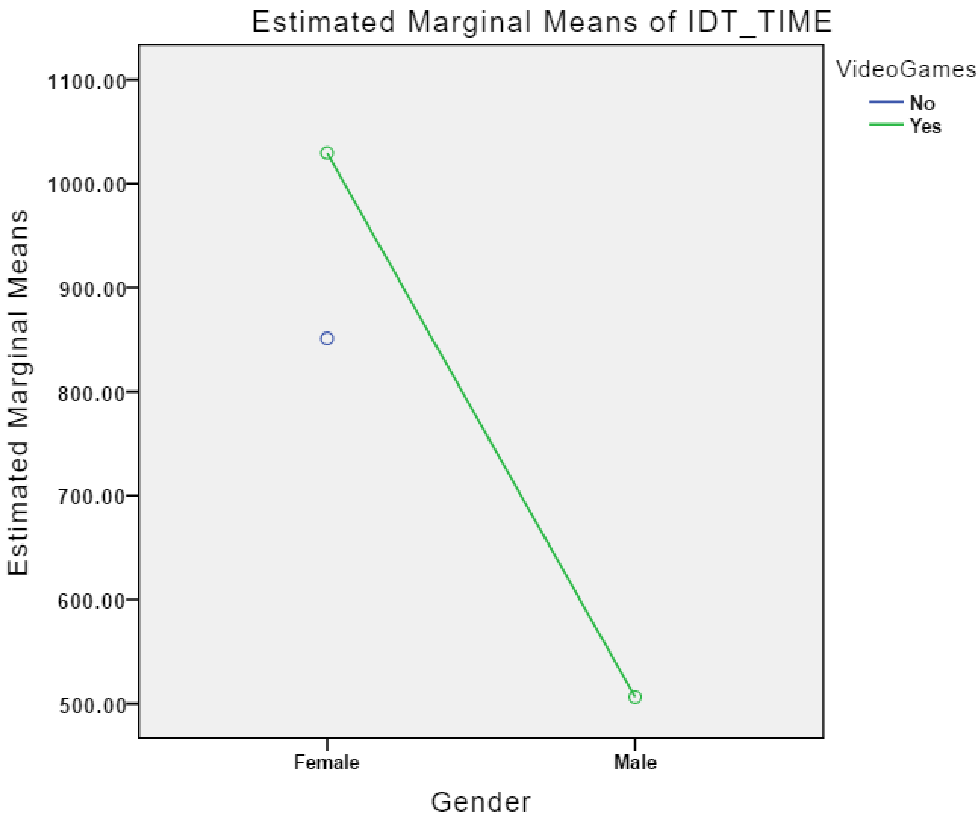
Tests of Between-Subjects Effects

Dependent Variable: IDT_TIME

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2083606.7[a]	2	1041803.35	2.646	.082
Intercept	12750628.4	1	12750628.4	32.381	.000
Gender	2070187.58	1	2070187.58	5.257	.027
VideoGames	159738.497	1	159738.497	.406	.527
Gender * VideoGames	.000	0	.	.	.
Error	17325729.9	44	393766.589		
Total	57071833.0	47			
Corrected Total	19409336.6	46			

a. R Squared = .107 (Adjusted R Squared = .067)

From the table above, the red, boxed p-value indicates there is a significant difference in the mean IDT time between males and females, regardless of whether they played video games. This difference is exemplified by the graph below.



The graph shows that the mean IDT time for males is lower than either of the female groups. From this graph, it is possible to see the difference in the means between the females who did play video games and the females who did not. The mean IDT time for females who did not play video games is lower than the mean IDT time for females who did play video games. It is important to remember when analyzing times, the lower the time, the faster the participant completed the activity. While completion time was not the most important factor considered in the assigning of the van Hiele levels, those with higher van Hiele levels usually had faster than average completion times. The table and accompanying graph only indicates that playing video games was not correlated to faster completion times for females, but cannot conclude anything about males since all males played video games.

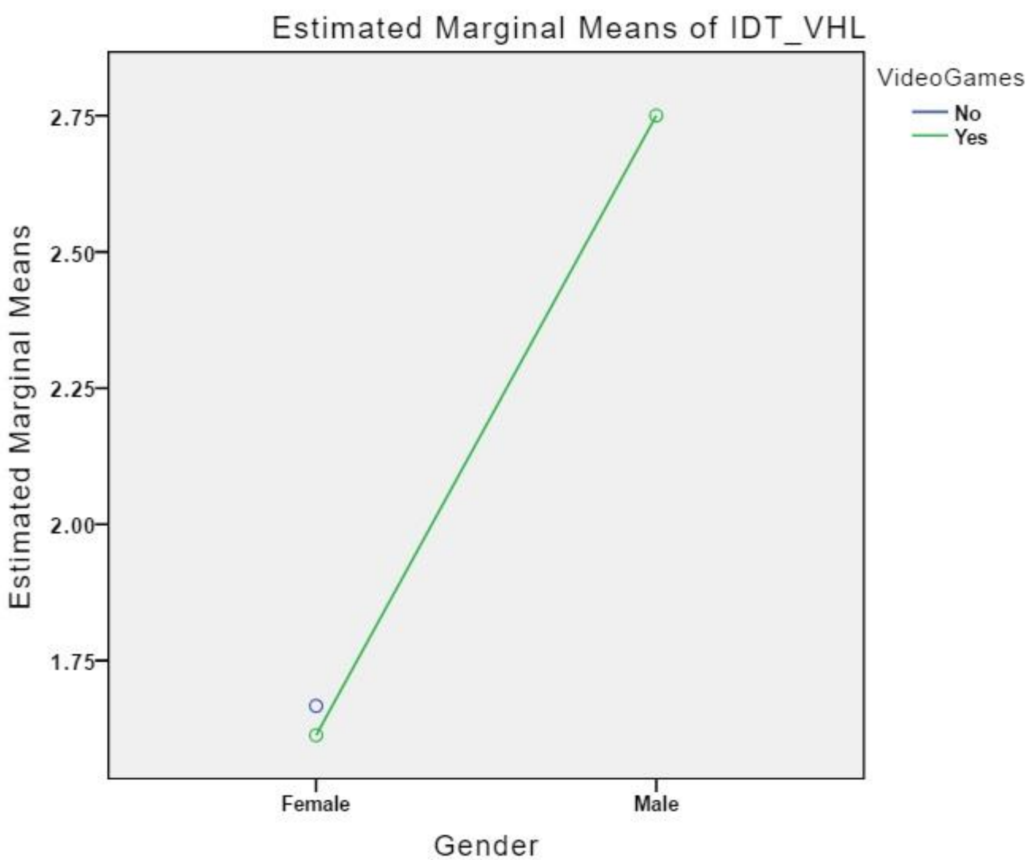
Tests of Between-Subjects Effects

Dependent Variable: IDT_VHL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10.038[a]	2	5.019	4.571	.016
Intercept	99.301	1	99.301	90.435	.000
Gender	9.776	1	9.776	8.903	.005
VideoGames	.015	1	.015	.013	.909
Gender * VideoGames	.000	0	.	.	.
Error	48.313	44	1.098		
Total	221.250	47			
Corrected Total	58.351	46			

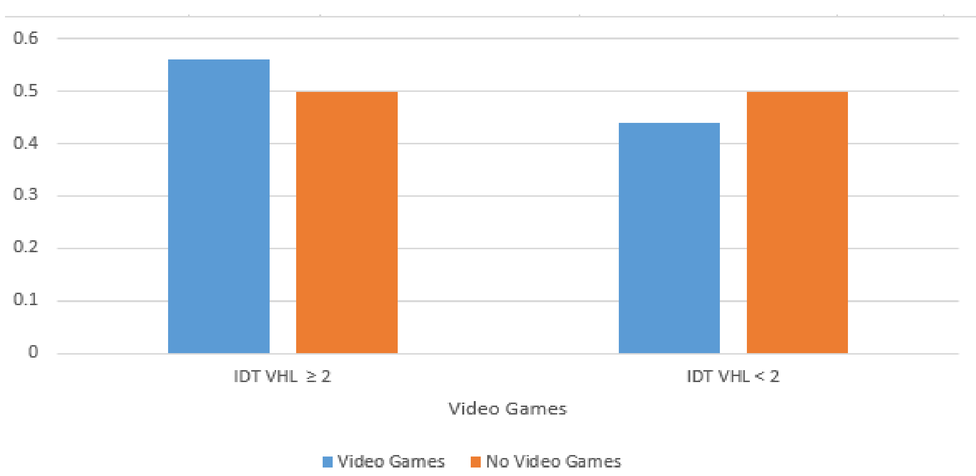
a. R Squared = .172 (Adjusted R Squared = .134)

From the two-way ANOVA table for IDT van Hiele level above, the red, boxed p-value indicates a significant difference in the mean IDT van Hiele levels between males and females, again regardless of whether they played video games or not. The graph below shows the mean for the IDT van Hiele level for males is higher than for either of the female groups. Similar to the



mean IDT time graph above, the mean IDT van Hiele level for females who did not play video games is higher than the mean IDT van Hiele level for females who did play video games, though the difference is rather insignificant.

Both of these ANOVAs are concurrent with previous literature in that there was a difference in IDT time and van Hiele level between males and females, favoring males. However, the primary research question explores whether or not playing video games is correlated to higher spatial visualization van Hiele levels. In order to strictly look at the effect of video games, gender did not need to be considered. First the van Hiele levels for the IDT were divided into low, less than 2, and high, greater than or equal to 2, scores. Using Microsoft Excel, a contingency table was constructed and yielded a side-by-side bar graph shown above. The bar graph indicates that the probability of having higher van Hiele levels given that a participant played video games is higher than if a participant did not play video games. While the correlation is slight, this research question can be answered in the affirmative, but only for the IDT van Hiele level.



From the surveys, there were only two participants who did not play sports at all. In order to run the two-way ANOVA, the groups had to be mutually exclusive. However, with one group only containing two participants, dividing the sample by playing sports or not playing sports was impractical. Therefore, the sample was split by whether a participant played ball sports, i.e. soccer, football, lacrosse, etc., or did not play ball sports. Participants who played both were put in the ball sports category. The groups were still uneven in number, albeit less severely, with only eight participants who did not play ball sports, five males and three females. The four two-way ANOVAs were run, and only one ANOVA yielded a p-value indicating significance, which was for the IDT van Hiele level. Again, no significant results were found for the tangram activity.

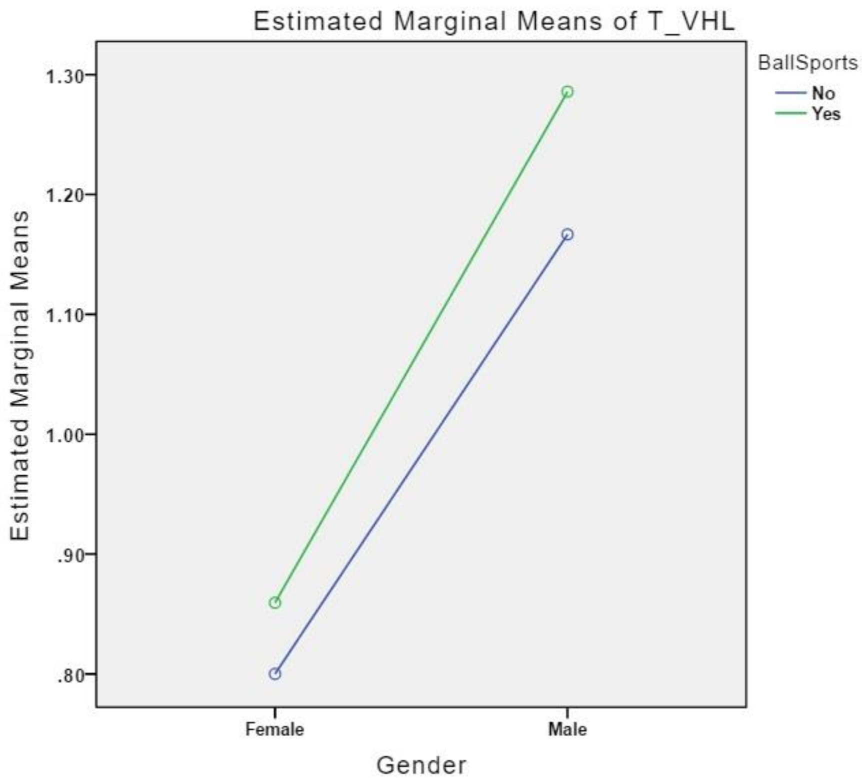
Tests of Between-Subjects Effects

Dependent Variable: IDT_VHL

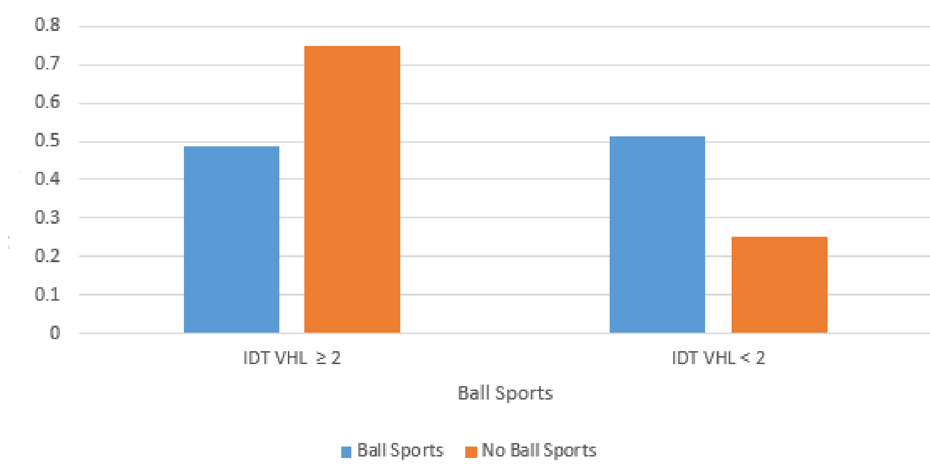
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11.987[a]	3	3.996	3.706	.019
Intercept	121.703	1	121.703	112.872	.000
Gender	4.664	1	4.664	4.325	.044
BallSports	.877	1	.877	.814	.372
Gender * BallSports	.427	1	.427	.396	.532
Error	46.364	43	1.078		
Total	221.250	47			
Corrected Total	58.351	46			

a. R Squared = .205 (Adjusted R Squared = .150)

As shown in the table above, the red, boxed p-value indicates a significant difference in the mean IDT van Hiele levels between males and females, regardless of whether the participant played ball sports. The graph below shows that the mean IDT van Hiele levels for all males were higher than either of the female groups. Means for both groups that played ball sports are higher than the means of both groups that did not play ball sports.



A similar contingency table was constructed for the explanatory variable: ball sports and the response variable: IDT van Hiele levels. The resulting side-by-side bar graph shown below indicates that playing ball sports is correlated to lower IDT van Hiele levels. The initial research question focused on playing sports rather than specifically ball sports. Therefore, the question cannot be fully answered since there were not enough participants that did not play ball sports to determine the effect.



The effect of geometry classroom experience on spatial visualization ability was also investigated. Responses were divided into four groups: lecture, lecture with some hands-on, hands-on with some lecture, and hands-on. Nineteen participants described their geometry classroom experience as lecture style, five were males. Twelve participants had a lecture with some hands-on geometry classroom experience, three were males. Only one male had a hands-on with some lecture geometry classroom experience out of the nine total. Similarly, there was only one male with a hands-on experience out of seven participants. The four ANOVAs were run as well as a post-hoc tukey HSD test on the independent variable geometry classroom experience in order to identify which specific groups indicated significant mean differences. None of the four ANOVAs had p-values that indicated significance. However, there were a few near significant p-values, which are worth mentioning.

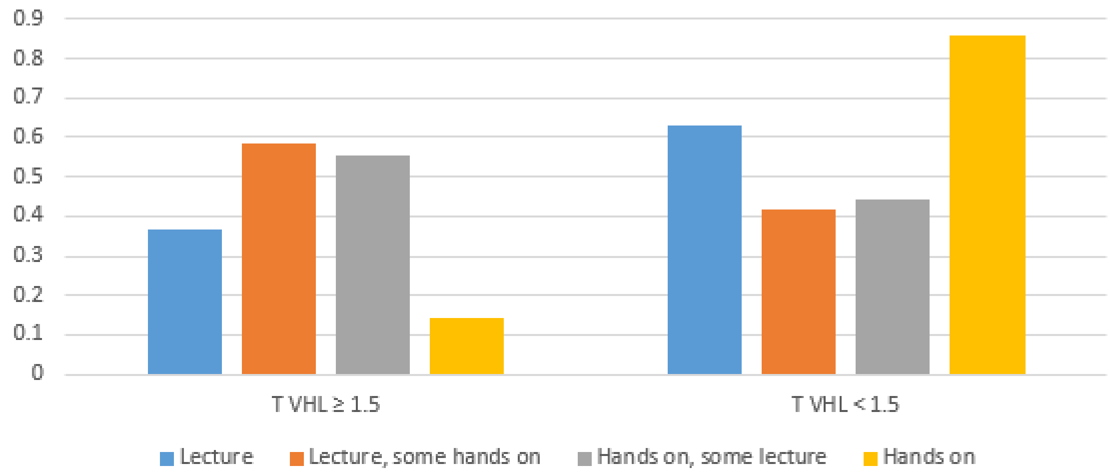
Multiple Comparisons

Dependent Variable: T_VHL
Tukey HSD

(I) GeometryExperience	(J) GeometryExperience	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Hands on	Hands on, some lecture	-.3889	.34429	.674	-1.3128	.5350
	Lecture, some hands on	-.8333	.32492	.066	-1.7052	.0385
	Lecture	-.3684	.30206	.618	-1.1790	.4421
Hands on, some lecture	Hands on	.3889	.34429	.674	-.5350	1.3128
	Lecture, some hands on	-.4444	.30126	.462	-1.2528	.3639
	Lecture	.0205	.27645	1.000	-.7214	.7623
Lecture, some hands on	Hands on	.8333	.32492	.066	-.0385	1.7052
	Hands on, some lecture	.4444	.30126	.462	-.3639	1.2528
	Lecture	.4649	.25191	.268	-.2111	1.1409
Lecture	Hands on	.3684	.30206	.618	-.4421	1.1790
	Hands on, some lecture	-.0205	.27645	1.000	-.7623	.7214
	Lecture, some hands on	-.4649	.25191	.268	-1.1409	.2111

Based on observed means.
The error term is Mean Square(Error) = .467.

The first of these near significant p-values comes from the tukey HSD post-hoc test. The red, boxed p-value in the table above indicates that there is a near significant difference in the mean tangram van Hiele levels between the hands-on group and the lecture with some hands-on group. As seen in the Mean Difference category, the difference between the mean of the hands-on group and the lecture with some hands-on group is -.8333, indicating the mean tangram van Hiele level of the lecture with some hands-on group is higher than the mean tangram van Hiele level of the hands-on group. This difference can be seen in the side-by-side bar graph.



The graph shows that lecture and hands-on geometry classroom experiences are more strongly correlated to lower tangram van Hiele levels. However, the two geometry classroom experiences that were correlated to higher scores were lecture with some hands-on, and hands-on with some lecture. The probability of having a higher tangram van Hiele level given lecture with some hands-on geometry classroom experience is higher than a hands-on geometry classroom experience as indicated from the table. The bar graph does imply that a lecture with some hands-on and hands-on with some lecture geometry classroom experiences are correlated to higher tangram van Hiele levels. However, no implications about what geometry classroom experience is the most conducive environment for spatial visualization ability improvement can be made.

The ANOVA for tangram time yielded a near significant p-value that indicates that the interaction between gender and geometry classroom experience has a near significant effect on the mean tangram time.

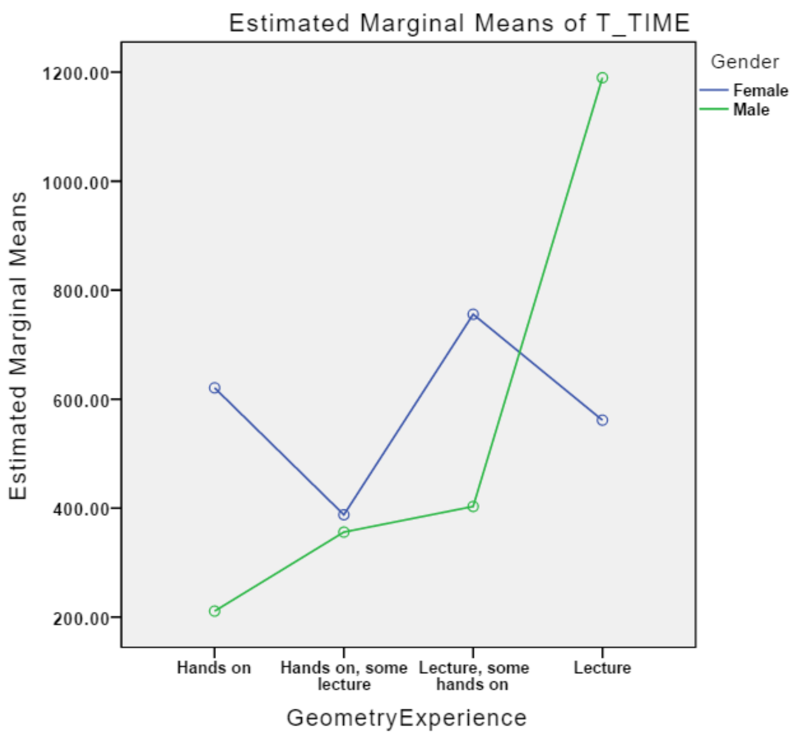
Tests of Between-Subjects Effects

Dependent Variable: T_TIME

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2646694.6[a]	7	378099.234	1.628	.156
Intercept	6689196.16	1	6689196.16	28.809	.000
Gender	9130.531	1	9130.531	.039	.844
GeometryExperience	1231916.50	3	410638.832	1.769	.169
Gender * GeometryExperience	1709438.06	3	569812.688	2.454	.078
Error	9055437.06	39	232190.694		
Total	29858322.0	47			
Corrected Total	11702131.7	46			

a. R Squared = .226 (Adjusted R Squared = .087)

This interaction between gender and geometry classroom experience can be seen from the graph below. However, the graph must be analyzed with a little scrutiny because the hands-on with some lecture and the hands-on groups only have one male in them. Therefore, this near significant p-value cannot confidently imply anything about the effect of geometry classroom experience on tangram van Hiele level.



Although it was not initially part of the original research questions, the effect of being a mathematics major on spatial visualization ability was investigated. Six of the males and two females were mathematics majors. Therefore, the effect of being a math major on spatial visualization became a point of interest because it may explain why the males had higher van Hiele levels than females for both activities. A chi-square test was used to test for an association between being a math major and high van Hiele levels. Of the four chi-square tests, the two that yielded p-values less than .05 were for the tangram van Hiele level and IDT van Hiele level.

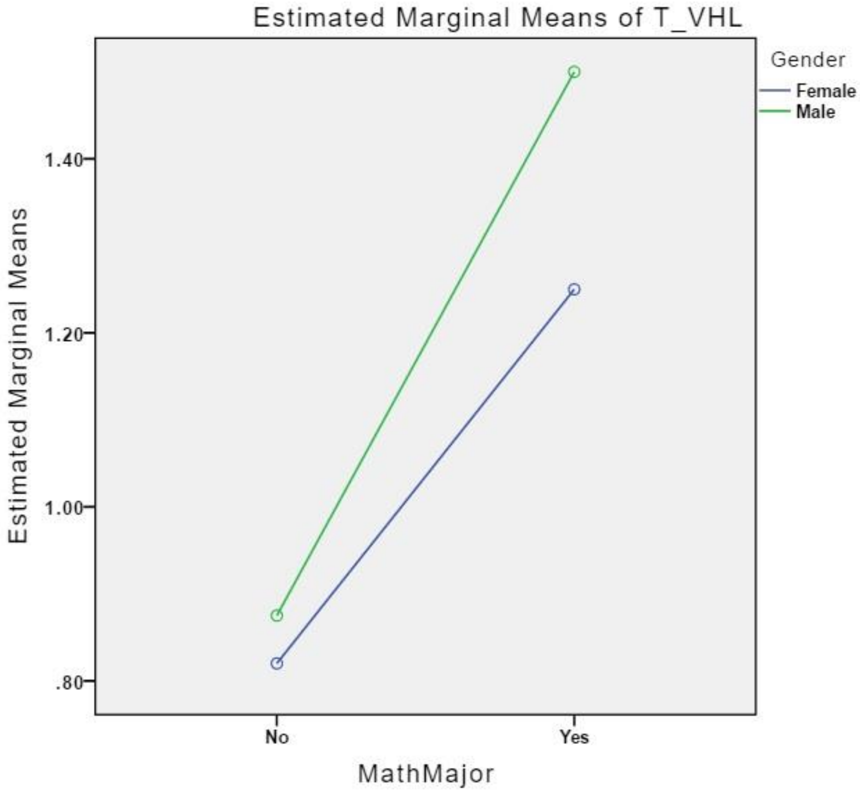
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.152[a]	1	.042		
Continuity Correction[b]	2.707	1	.100		
Likelihood Ratio	4.192	1	.041		
Fisher's Exact Test				.057	.050
Linear-by-Linear Association	4.064	1	.044		
N of Valid Cases	47				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.40.

b. Computed only for a 2x2 table

The red, boxed p-value in the table above indicates a strong association between being a math major and higher tangram van Hiele levels. This association can be seen from the graph of the estimated marginal means given by the ANOVA shown below. The graph shows that regardless of gender, male and females who were math majors had a mean tangram van Hiele levels higher than the groups who were not math majors. Again, from the graph we also see the difference in mean tangram van Hiele level between males and females regardless of major.



The chi-square test for IDT van Hiele level is shown in the table below. The red boxed p-value indicates and even stronger association between being a math major and higher IDT van Hiele levels. This is association is displayed in the graph. Similar to the graph for the tangram

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.558[a]	1	.033		
Continuity Correction[b]	3.048	1	.081		
Likelihood Ratio	5.101	1	.024		
Fisher's Exact Test				.052	.037
Linear-by-Linear Association	4.461	1	.035		
N of Valid Cases	47				

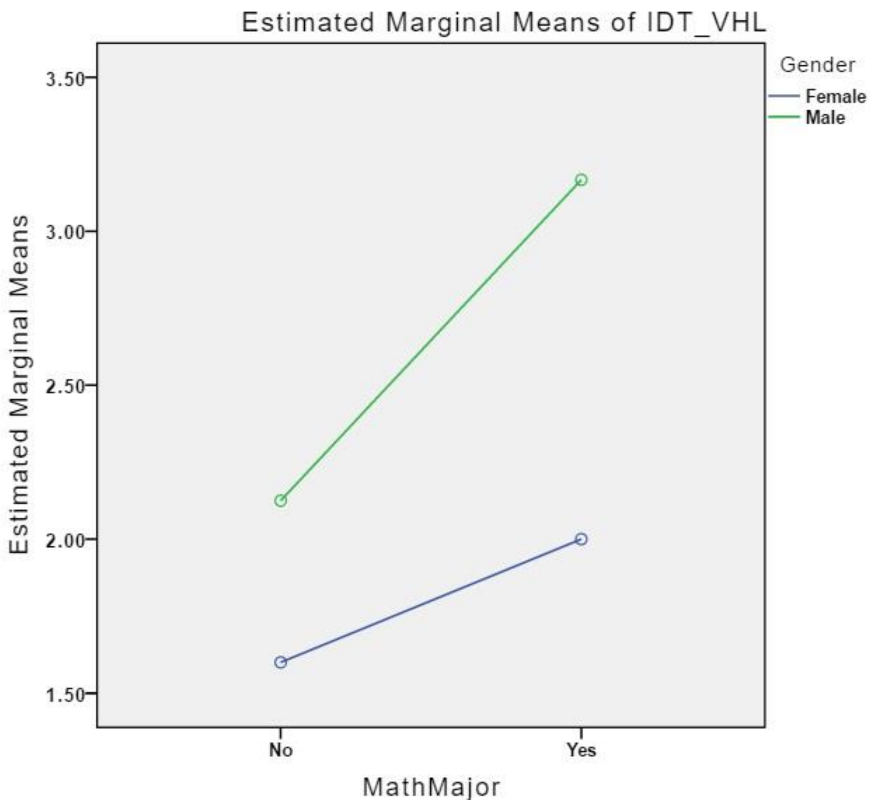
a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.74.

b. Computed only for a 2x2 table

activity above, the mean IDT van Hiele levels are higher for male and female math major groups than the not math major participants. The graph again shows the difference in mean IDT van

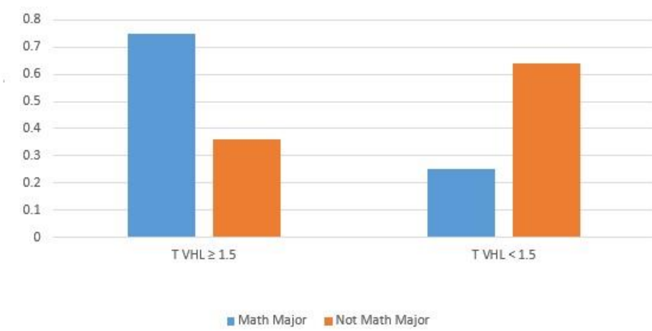
Hiele levels of males, regardless of major are higher than the mean IDT van Hiele level of females.

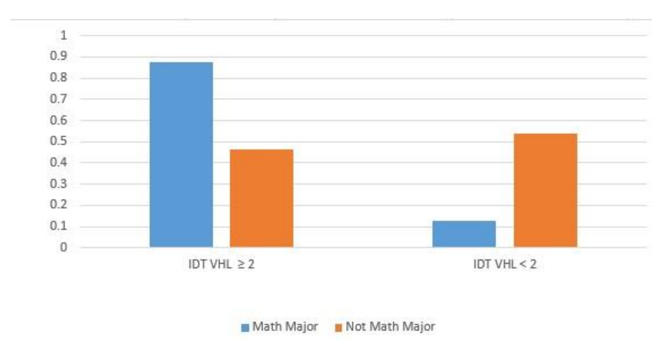
To truly investigate the effect of being a math major on a participant's spatial visualization ability, contingency tables for both the IDT and tangram van Hiele levels using



math major as the explanatory variable. .

The graphs exemplify the strong correlation between being a math major and higher van Hiele levels for both the tangram and IDT. A factor that needs to be taken into consideration when analyzing the effect of majoring in mathematics on spatial visualization is that the





majority, though not all, of the participants that were not mathematics majors were GC preservice teachers in the early childhood education major. Therefore, this association of being a math majors to higher van Hiele levels cannot be generalized since the rest of the sample these eight participants were compared to did not have a variety of majors. Rather it was more of a comparison between two majors.

In summary the data reveals the following:

- Playing video games is slightly, positively correlated to higher van Hiele levels for the IDT and nearly so for the tangram activity.
- There is no conclusive correlation between playing ball sports and higher van Hiele levels for either activity.
- Geometry classroom experiences were only correlated to higher van Hiele levels for the tangram activity for the lecture some hands on group and the hands on with some lecture group. The lecture with some hands on group had a higher mean tangram van Hiele level than the hands on group, regardless of gender. However, no implications can be made due to the subjectivity of the participants' responses to the survey.
- Being a math major is strongly correlated to higher van Hiele levels for both the tangram and the IDT.

Discussion

Before delving into the implications and limitations of the study, it is important to look at the cases for the fastest completion times for the tangram and the IDT activities. Firstly, the fastest completion times for both activities were not from the same participant. In fact these particular participants are interestingly opposite.

The participant with the fastest completion time for the tangram activity was a female preservice teacher in the early childhood education major. She completed the tangram in thirty seconds and was assigned a van Hiele level of 2. Her survey revealed that she "maybe once a week…if that" played video games which were either puzzle, strategy/tactics, or dance/rhythms. She played tennis, soccer, softball, did dance/gymnastics, and cheerleading. She described her geometry classroom experience as "95% lecture some hands on." She also had a relatively fast completion time for the IDT and was assigned a van Hiele level of 4. Her case is interesting in that the results of this study are not consistent with her success given that males tended to have higher mean van Hiele levels and lower mean times all around, and being a math major was associated to higher van Hiele levels.

A male had the fastest IDT completion time at two minutes and 14 seconds with a van Hiele level of 3.5. He had experiences almost opposite to hers. This participant played shooter, first-person shooter, RPG, strategy/tactics, and dance/rhythms video games ranging from five to fifteen hours a week. However, he did not play ball sports. His success is consistent with the results of this study since he was also a mathematics major. His tangram time was also above average and earned him a van Hiele level of 2.

The results indicate that playing video games may give a student a slight advantage in learning three-dimensional geometry concepts. The data indicates there is a slight positive correlation between playing video games and higher spatial visualization van Hiele levels; though it is not statistically significant. This is consistent with Gagnon's study which found that participants benefitted from playing video games. As for playing ball sports, the data does not indicate any advantage at all.

The use of prodding and prompting questions (Abney, 2007), as outlined in the characterization of the van Hiele levels for the two activities, was useful to the students who needed assistance in completing the activities. While the questions did not directly tell the students how to complete the activities, the use of these two question types allowed the students to redirect their mental processes eventually leading to the making of correct and appropriate connections. To gauge the full effect of these types of questions on a participant's success in geometry activities, such as the ones from this study, would require a new study all together. However, types of questions such as prodding and prompting may be helpful in students attaining a new van Hiele level or improving the acquisition of their current level for an activity or concept.

The limitations of the study primarily stemmed from the less than ideal sample. The intended sample was supposed to have an even sampling of the three groups as described in the methods section: targeted video game players at GC, GC athletes, and GC's MAED 3002 class. Since participants volunteered to participate, there was a lack of participation from the first two groups. The preservice teachers were given an incentive to participate. Not only was there a lack of even sampling between the groups, males were outnumbered almost five to one. Six of the ten male participants were mathematics majors. This is a confounding variable that may explain the differences between males and females. Only two of the females were math majors, and four of the males were not math majors, so unlike the study done by Fennema and Sherman in 1978, it would have been impossible to truly compare the sex differences between male and female non math majors or male and female math majors due to the sample size and unevenness in the number of males versus females. Since the sample was so intentional but limited in participation from the groups, the results and implications of this study are essentially limited to the sample; unable to be applied to a general population.

Therefore, in order to continue to study the effects of playing video games or sports on spatial visualization ability in future research using the same methods as outlined earlier would require a larger and more diverse sample. The differences between the sexes that were found may have been a result of the lack of diversity in major amongst the male participants seeing as most were math majors and all were in STEM fields. However, getting athletes and video game players to participate would require some sort of incentive since a volunteer based sample was not sufficient for the current study. The study also only answered the question of yes or no to playing video games or ball sports. Future research into what types of video games or what types of sports may affect spatial visualization ability would be the logical next step.

This particular study did not yield particularly influential results and implications to mathematics classrooms. However, it may open the door to more research into the experiences that may help to eliminate these differences in spatial visualization ability all together.

Appendix A

1) What type of videogames did you play as a child? Check all that apply. In the space below indicate how long you played these videogames, i.e. 2 hours a day, 5 hours a week, etc.
   ☐ Shooter

   ☐ First Person Shooter

   ☐ Adventure

   ☐ Platform

   ☐ Role Playing Games

   ☐ Puzzle

   ☐ Simulation

   ☐ Strategy/Tactics

   ☐ Sports

   ☐ Fighting

   ☐ Dance/Rhythms

   ☐ Survival/Horrors

   ☐ Hybrids

   ☐ Other ____________________________________
2) What age were you when you started playing videogames?

3) What sports did you play as a child? Check all that apply. In the space below indicate how long you played these sports, i.e. 3 years.
   ☐ Tennis

   ☐ Track and Field

   ☐ Golf

   ☐ Football

- ☐ Baseball
- ☐ Basketball
- ☐ Hockey
- ☐ Soccer
- ☐ Lacrosse
- ☐ Volleyball
- ☐ Dance/Gymnastics
- ☐ Cheerleading
- ☐ Softball
- ☐ Other ____________________________________

4) What age were you when you started playing sports?

5) On the scale below mark where the majority of your geometric classroom experience.
Lecture style (formulas were given)……………………………………………………………Hands on activities

6) How would you describe the experiences you had in learning geometry? (Lecture style, hands on activities, etc.)

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