The Effect of Drawing Instruction on Geometry Achievement in High School Students

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Abstract

Successful completion of geometry is a necessary stepping-stone into STEM (science, technology, engineering, and mathematics) fields. There is a strong correlation between spatial ability and success in both geometry and the visual arts. Successful visual arts students have extensive training and experience in manipulating spatial relationships between objects. Multiple studies have shown that training can improve performance on spatial ability tests. This proposed experimental study will investigate the effect of drawing lessons on geometry achievement in high school students as measured by a standardized geometry achievement test to be developed for this study.

Keywords: geometry achievement, spatial ability, STEM, drawing

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To maintain its position as a world leader in innovation, the United States is under a nationwide push to increase STEM education opportunities and successes. Yet, the United States currently has one of the lowest STEM to non-STEM degree rates in the world. (Thompsons & Bolin, 2011). Only 16 percent of American high seniors are proficient in mathematics and are interested in a STEM careers ("Science, Technology, Engineering," 2015) In an effort to meet anticipated needs, funding flows to STEM programs ("Science, Technology, Engineering," 2015). At the same time funding for arts visual programs is decreasing, and visual art instruction program offerings are declining in both public elementary and public high schools. ("Arts Education," 2012).

Success in STEM fields is dependent upon success in advanced mathematics, and geometry is considered a gateway course for advanced mathematical study (Weckbacher& Okamoto, 2014). Strauss (2014) argues that geometry encompasses all of mathematics, highlighting the "mutual coherence between the aspects of number and space" Having good spatial skills strongly predicts achievement and attainment in science, technology, engineering, and mathematics fields (Wai, Lubinski, & Benbow, 2009). Are spatial abilities innate and immutable? While infants display innate visuospatial understanding (Xu & Rosa, 2007) and high achieving art students score strongly on spatial tests, spatial skill is not limited to native ability. Research indicates that spatial abilities can be purposefully improved through training and practice (Wallace & Hofelich, 1992; Sung, Shih & Chang, 2015).

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Literature Review

Van Hieles' developmental model. Much of current geometry instruction is based on the Van Hiele developmental model developed by Diana van Hiele-Geldof and her husband

Piere Marie van Hiele in 1957 (Usiskin, 1982). The model divides geometric concepts into five hierarchical discontinuous levels of understanding:

1. visualization: names and shapes of figures as entities recognized by their appearance;
2. analysis: identify characteristics and classification of shapes;
3. informal deduction: deduce properties of a figure and recognizes classes of figures;
4. deduction: understand the roles of postulates, theorems, and construct proofs and make;
5. rigor: the student is able to make abstract deductions. (Crowley, 1987) .

Readiness for geometry instruction is achieved by assessing a student's current level and providing interventions to move them through the sequence. Attainment of level 4 is necessary for success in geometry. If there is a mismatch of student level and level of instruction, learning may not occur(Usiskin, 1982).

Van Hieles' theory has been studied extensively and has had a great influence on the development of many sets of geometry standards, including the Common Core (Steltenphol, 2014). More recent research calls into question the sequential nature of the theory. Levels have been shown to be continuous, rather than discrete, and dependent upon problem solving abilities using spatial visualization (Owens & Outhred, 2006).

Spatial abilities. Visuospatial or spatial ability is the ability to interpret spatial relationships between objects and can be measured with tests of the recognition of impossible figures and mental rotation. Undergraduate art students display high spatial ability (Chan, 2008), and infants as young as six months old demonstrate an ability to differentiate between different visuospatial arrays (Xu & Rosa, 2007).

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Very early spatial sense plays a supportive role in the development of number sense, imagining quantity, size, and shape (van Nes & de Lange, 2007). While infants can differentiate spatial differences, the pre-numerical knowledge of preschool children allows them to make quantitative comparisons (Casey et al., 2015). Early spatial sense may drive the development of more formal mathematical skills (van Nes & de Lange, 2007). In a study of fifth-grade girls, first-grade spatial skills were the strongest predictor of fifth-grade math reasoning (Casey et al., 2015). A longitudinal study found that high school students' spatial abilities strongly predicted achievement in science, technology, engineering, and mathematics fields (Wai, Lubinski, & Benbow, 2009).

Multiple studies show a significant relationship between spatial abilities and geometry achievement (Wai, Lubinski, & Benbow, 2009; Weckbacher &Okamoto, 2014). Visuospatial ability requires reasoning with figures and shapes. In a study of undergraduates, high performance predicted deductive reasoning performance (Bacon, Handley, Dennis & Newstead, 2007). Success in geometry requires both inductive and deductive reasoning skills (Lachmy, Koichu, 2014). Spatial visualization has shown to be a predictor of both inductive and deductive reasoning ability in high school geometry students (Eastman & Carry, 1975)

Recognition of the importance of spatial abilities to practitioners of the visual arts prompted Wai, Lubinski, and Benbow (2009) to include visual arts occupations in their longitudinal study of the relationship between spatial ability and STEM achievement. Two recent studies illustrate the positive correlation between spatial ability and drawing ability. Undergraduate art students who scored high in image control and spatial analysis skills demonstratestrong in-depth drawing techniques (Perez-Fabello, Campos & Meana, 2014).

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Conversely, undergraduate art students judged to have high drawing ability score high on spatial ability tests (Chan, 2008; Chan, 2009).

Innate spatial ability most likely plays a role in achievement in the visual arts and STEM fields. But, predisposition is not predetermination. Several studies have shown that spatial abilities are malleable. Line drawing exercises resulted in significant increases in visual imagery control (Wallace & Hofelich, 1992). Research using both static and animated training resulted in significant gains in spatial ability tests. Animated training produced somewhat greater gains than static training in measureable spatial abilities (Samsudin, Rafi & Hanif, 2011; Lowe, 2003)

Purpose. Training has been shown to improve spatial skills. Is there a transitive relationship between spatial skills training and geometry achievement? Spatial training has been shown to increase reasoning skills in adult subjects (Gazes, Lazareva, Bergene& Hampton, 2014). Will spatial training have an effect on geometry achievement? The purpose of this proposed study is to investigate the effect that training designed to increase spatial abilities has on geometry achievement in high school students as measured by results on an achievement test developed for this study.

Research question. Will a sequence of drawing lessons increase geometry achievement in high school geometry students?

Hypothesis. Students who have received drawing instruction will demonstrate greater geometry achievement over time.

Method

Participant Selection and Assignment

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Comment [12]: Your literature review section isn't really a review at all—it is a stringing together of sentences and citations. I don't learn anything about any study or read an explanation of how they lead to your proposed study.
There are also many issues with punctuation especially around citations. There are not really paragraphs. You need to carefully construct a logical argument—through the use of information from the studies you have read. Each paragraph needs a topic sentence.

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Participants will be drawn from high schools in a large Northern Virginia school districtthat encompasses a large geographic area. There are 22 high schools in the district. In order to obtain the most diverse representative sample possible the selection will be stratified by school: Two classroom clusters will be randomly selected from each high school.

Of the two clusters from each school, one will be randomly assigned to the treatment group and the other will be assigned to the control group, resulting in 22 classroom clusters in the treatment group and 22 classroom clusters in the control group. Average class size in this district is 29.5, resulting in an anticipated total of 649 subjects ("FCPS Profile," 2013).

Research Design

This study will have a nonequivalent groups pretest posttest quasi-experimental design.

H_o: Completion of drawing lessons will have no effect on geometry achievement

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The independent variable is the presence or absence of drawing lessons measured by evidence of completion of provided drawing lessons by the treatment group. The dependent variable is math achievement measured by students' results on the geometry achievement test developed for this study. An independent covariate is previous or concurrent art instruction or experience, which will be measured with a Likert type survey of previous drawing experience that will be developed for this study.

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Instruments

Geometry achievement test. Student achievement in geometry is currently measured in the district using an end of course standardized test that geometry students are required to take called the Virginia Standards of Learning (SOL) in Geometry. Readily available existing released SOL tests will not be used in this study in order to eliminate the history threat that exposure to readily available tests may vary between classrooms. A unique instrument will be developed for measuring geometry achievement drawn from existing SOL tests. The test will contain both multiple choice and free response questions. The instrument will be checked for face validity by presenting it for review to current high school geometry teachers who are not involved in the study to confirm that it covers the materials necessary for achievement in high school geometry. The instrument will be revised according to recommendations and resubmitted for review.

The geometry assessment will be pilot tested by high schools students who are not involved in the study. Comparing pilot testers' results on the developed instrument with scores on a released SOL Geometry test will test construct validity. The instrument will be corrected and adjusted and retested before use in the study.

Drawing lessons. An online drawing unit will be developed that will present three basic elements of drawing:

1. Line (one dimensional):
    a. Definition;
    b. Direction;
    c. Texture;
    d. Thickness;
    e. Identification of lines in presented examples.
2. Shape (2 dimensional):
    a. Definition;
    b. Positive and negative space;

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c. Identification of simple and complex shapes;

d. Identification of simple and complex shapes in provided examples.

3. Value (2 and 3 dimensional):

a. Definition;

b. Representation of 2 dimensions using shading presented in provided examples;

c. Representation of 3 dimensions using shading presented in provided samples.

A rubric for successful completion for each of the drawing lessons will be developed and tested for interrater reliability before use in the field.

Control treatment. To control for the novelty effect, a three-lesson course on the history of geometry will be developed and presented online to the students in the control group. In order to make sure that the content is not correlated with geometry achievement the course will be assessed for exclusion of content that may impact measures of geometry achievement.

Previous art experiences. A Likert-type survey will be developed to collect information on students' prior formal and informal art experiences. More weight will be given to formal instruction, defined as art classes taken currently or previously at the middle school or high school level.

Procedures

Participants will be members of class clusters randomly drawn from geometry classes in the sample district. Classes will be randomly assigned to the control or the treatment group.

A consent form will be sent to the parents of the students that will outline the purpose and the procedures of the study. Freedom from obligation for their student to participate, freedom to opt out at any point, along with contact information for the researcher will be provided. Additionally, the steps to be taken to ensure privacy and confidentiality will be included.

It is assumed that high school geometry student have the capability of providing assent. An assent form containing the same information as the parental consent form will be provided to the subjects.Once consent and assent are received,the art experience survey will be administered during class time.

On a following day the developed geometry achievement test will be administered online at a testing center within the school and results will be reported to the researcher.

To maintain treatment fidelity across multiple classroom clusters, the online drawing lessons will be presented to the treatment classroom groups within their classrooms once a week over the course of three successive weeks. Successful completion of the lessons will be demonstrated by students' completion of pencil on paper drawings that incorporate the presented element in response to a prompt given at the end of each lesson. The teacher will collect the drawings from the students at the end of each lesson and report completion for each student according to the supplied rubric. Drawings will be returned to the students at the end of the study.

The control group will receive the online delivered geometry history lessons within their classrooms in the same timeframe as the treatment group receives the drawing lessons.

The week following the completion of the presentation of the online courses, both the control group and the treatment group will retake the developed geometry assessment online and the results will be reported to the researcher.

Proposed Preliminary Data Analysis

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Analysis of covariance (ANCOVA) will be used to compare the results of the control and the treatment group and to control for the possible effect that prior art training and experience may have on the analysis of the effect of the treatment on outcomes.

Ethical Considerations

This study presents no perceived possibility for harm since both the treatment and the control treatment are additive, non-controversial content. Multiple testing cycles do place a time and test burden on the subjects and the teacher. Online delivery of treatments and tests spaced over the course of several weekswill possibly reduce the potential burden. Also, a sufficient time interval between achievement test administrations should reduce the interruption to regular classroom activities.

Steps will be taken to ensure privacy and confidentiality for all subjects. Only the classroom teacher and the researcher will have access to identifying information during the duration of the experiment. Once all data has been collected, all identifiers will be removed and a numerical coding system will be used during data analysis. No identifying information will be included in the final report.

Results of the study will be made available to the study participants at the conclusion of the study if contact information has been provided to the researcher.

It is hoped that the results of this study will add to our existing knowledge of the relationship between spatial understanding and mathematical achievement.

and Validity

In this quasi-experimental design a testing threat exists because of the reuse of the same instrument to pretest and posttest geometry achievement. This threat could be removed by development of a second achievement test equated to the first however……

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Because every classroom has a different environment and the students' experience can vary from classroom to classroom depending on the effectiveness of the teacher, the time of day and other possible differences, there is a history threat to validity. This is partly mitigated by the quantity of classrooms involved.

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Differential selection threat exists because of the nature of cluster assignment of subjects. The large number of classroom groups should lessen this threat. Random assignment of individuals would remove the threat. But cannot be done because…….

The population to be represented in this study is high school geometry students in the United States. Though the selected district is ethnically and socio-economically diverse, there are some significant demographic differences thatshould to be taken into consideration when generalizing results including . . . . .???("About FCPS," 2015; "State and County QuickFacts," 2013)

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