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ABSTRACT

This study examined the effects of level of instructional scaffolding on students' use of Geometer's Sketchpad and other software tools in a technology-integrated geometry curriculum. In order to revitalize education at the secondary level and in particular in the mathematics curriculum, educational reformers have advocated the incorporation of appropriate technologies to support learner-centered environments. The goal was to determine the relative effectiveness of a teacher-directed approach compared to a student-directed approach of utilizing Sketchpad to complete a project-based learning task. In general, and in the short term, the instructional model where the teacher provided structure and directed the problem solving activities of the students resulted in learner outcomes characterized by greater understanding of the concepts and less frustration with the process of using Sketchpad. However, many students in the self-directed group expressed a sense of self-confidence and pleasure with their accomplishments. (Contains 15 references and 2 figures.) (Author)

Learning Geometry Dynamically: Teacher Structure or Facilitation?

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Abstract

This study examined the effects of level of instructional scaffolding on students' use of Geometer's Sketchpad and other software tools in a technology-integrated geometry curriculum. In order to revitalize education at the secondary level and in particular in the mathematics curriculum, educational reformers have advocated the incorporation of appropriate technologies to support learner-centered environments. The goal was to determine the relative effectiveness of a teacher directed approach compared to a student-directed approach of utilizing Sketchpad to complete a project-based learning task. . In general, in the short term, the instructional model where the teacher provided structure and directed the problem solving activities of the students resulted in learner outcomes characterized by greater understanding of the concepts and less frustration with the process of using Sketchpad. However, many students in the self-directed group expressed a sense of self–confidence and pleasure with their accomplishments.

Perspectives

Mathematics education is frequently characterized by instruction that is shallow in nature and requires students to remember an assortment of facts (Stigler & Hiebert, 1997). A number of documents emerging from efforts to improve the mathematics achievement of our students offer recommendations for instructional reform (NCTM, 1989; National Research Council, 1989). It is generally agreed that to facilitate the problem solving capacity of the learner, teachers must provide them with authentic classroom activities where they are required to apply knowledge as well acquire it (Brown, Collins, & Duguid, 1989). A recent report to the President's Committee of Advisors on Science and Technology (PCAST, 1997) recommended that allocations of funding for computers and information technology be increased in the K-12 schools. The report urged that these allocations be used for instructional applications that are designed to support the active constructions of knowledge and expressed optimism that these applications would have a positive impact on student learning outcomes. In response to these mandates pre-service and professional development programs have been designed to facilitate new teaching strategies that incorporate technologies that support learner constructions of knowledge.

A fundamental question in the design of learner-centered instruction is how much structure as well as learning control to give to students (i.e., learner control) so that learning is optimized. This structure versus learner control continuum can range from complete learner control of everything, which Snow (1980) describes as the 'Adult Scholar Model' to one where the learning task is highly structured and the learner has virtually no control, which Snow refers to as 'Child Robot Model'. Increased structure has the advantages of increasing learners' perception of guidance, where they are directed through the task completion process step-by-step, and there is more uniformity of learning outcomes with specific outcome expectations. Less structure, on the other hand, intends to promote more learner choices, more learner control and self-regulation, thereby encouraging more creativity and better meta-cognitive skills.

There is general agreement (Battista, 1999; Greeno, Collins, & Resnick, 1996; Schoenfeld, 1994) that for optimal learning of mathematics, ideas must be constructed by the learner. NCTM Standards (2000) suggest that students should be engaged in inquiry and problem solving while they solve complex and interesting problems. Technology environments to support the mathematics curriculum have evolved such that there are powerful programs available to support inquiry, reasoning, and problem solving in conducting mathematics tasks (Wiest, 2001). One program, which fits these criteria, is Geometer's Sketchpad (1993), a dynamic geometry program, which can be used to support a constructivist approach to instruction. Teachers can implement this program by providing various levels of structure and it has been suggested that further inquiry be conducted to establish the benefits of different instructional approaches (Hannafin & Scott, 2001). The present research extends previous studies that investigated the process of using this software (Hannafin & Scott, 2001). It also was initiated in response to recommendations to conduct research under conditions that are typical classroom contexts.

Research Questions

The specific questions that guided this research were:

1. Does the instructional approach influence students' conceptual understanding of geometry and in particular, transformations?
2. What were the students' perceptions of the support provided by the instructor, challenges, frustrations, and successes while working on the project-based learning activities?

Methods

The mixed method design of this study incorporated both quantitative and qualitative research strategies. Quantitative measures of achievement were obtained to provide an evaluation of students' knowledge of and their ability to apply geometric concepts. Qualitative methodologies including observation and content analysis were utilized to provide insights to the learning process and perceptions of the students.

Participants

The participants were 82 primarily tenth-grade students from four geometry classes that met daily for 50-minute sessions. The setting for this study was an all-female secondary private parochial academy that is nationally recognized for its academic excellence and innovations in the integration and immersion of technology into the curriculum. Gender differences on mathematics achievement tests have been noted and indicate that males do better on items with algebraic content, applied real life-type items and items classified at higher levels of cognitive complexity (Bielinski & Davison, 1998). An important goal in the mission of this school is to provide females with rich learning environments in mathematics and science to enhance their opportunities to develop expertise in those curricular areas. Students, teachers, and administrators are expected to be proficient at using technology for academic purposes. All students were equipped with their own personal laptop computers that were connected to both an Intranet and the Internet via wireless technologies available throughout the campus.

Instructional Context

The instructor for this course implemented a mathematics learning environment that was enriched through the technologies available to the students. Students were provided with

Geometer's Sketchpad (1993), a program that provides a way to construct geometric figures much like the traditional tools of geometry: the ruler, protractor, straightedge, and compass. Students were required to use word processing tools to take notes, record their observations, to prepare reports about their discoveries and to complete all exercises. This "electronic notebook" takes the place of traditional spiral and three ring binders and requires that students become proficient at using word processing tools, particularly the inclusion of equations and mathematical symbols, the insertion of graphics, and the inclusion of OLE embedded items. Blackboard, an online course management system, provided students access to course announcements, assignments and activities, course documents, collaboration tools (communication and digital file exchange), and an online assessment feature.

Project-Based Learning Activity

Student projects offer an ideal situation to provide problem solving opportunities that present real world problems that are scaled back so that they are doable in the confines of the classroom.. Project-based learning can be thought of as learning through a series of theme related activities that are based in authentic, real-world problems in which the learner has a certain amount of control over the learning environment and the design of the learning activities (Slavin, 1995). The goal of this project was to design and determine the cost of setting up a low maintenance garden to be located somewhere on the grounds of the school's campus. The project was conducted over a period of 4 weeks during which students worked collaboratively to complete the project tasks. Student groups were requested to tour the campus, identify the location for their garden, lay out the perimeter, and using yard sticks identify the measurements of the garden perimeter. The groups were required to identify a theme for the garden, design the garden, develop a scale drawing depicting the garden's dimensions, design garden areas for paths, seating, flowers, shrubs, and trees. Geometer's Sketchpad was to be utilized to draw the garden plan with its various sections. Sketchpad options that could be used to facilitate the design process include transformations, constructions, and graphing. Subsequent activities included the selection of types and quantity of plants, soil and fertilizer, edging and path materials, and ground covers.

Geometer's Sketchpad

This dynamic geometry program (Key Curriculum Press, 1993) is a tool that can be used to support a constructivist learning environment. It contains no instructional agenda and its use depends on the way that the teacher decides to utilize it. A distinction between just providing the tool to students and how the teacher actually integrates the use of the tool in the instructional process has been made (Pea, 1993). Sketchpad is a dynamic tool, allowing students to not only construct geometric figures, but provides a way for these figures to be manipulated giving students an opportunity to explore and discover principles of geometry. Students can construct an object and then explore its mathematical properties by dragging the object with the mouse. It is recommended that students work collaboratively with this tool to visualize, analyze problems, and make conjectures. Some of the tools available in this environment include drawing tools which allow students to create Euclidean constructions using transformation commands to construct translations, reflections, rotations, dilations, and iterations by fixed, computed, and dynamic quantities.

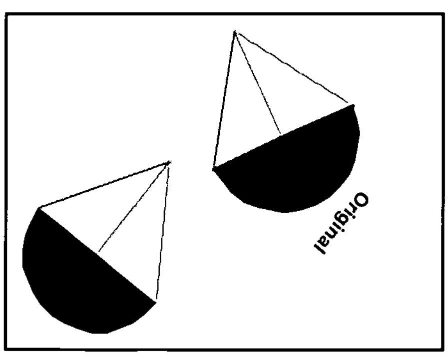
Procedures

The four classes were randomly assigned to one of the two instructional models (structured problem solving or student-generated problems with teacher facilitation). In both models students were organized into groups of three to work collaboratively to complete class projects. Students were encouraged to share their ideas and to develop geometric thought through this collaboration. Students in all classes were given the project-based learning activity on designing a garden. In Model 1: Structured Problem Solving (SPS) students were provided with specific problems to solve and given a set of guidelines and strategies to follow in completing their problem-solving task. Specific tasks designed to facilitate the achievement of instructional objectives were presented in the Group section of Blackboard. At the beginning of each class the instructor demonstrated specific concepts related to transformation and discussed the application of these concepts to the project. In Model 2: Student-Generated, Teacher-Facilitated (SGTF) students were provided with the same problem-based learning activity, but were responsible for identifying the information and strategies they needed to solve the problem. They were directed to utilize their Group section of Blackboard to think through their problem and to request assistance from the teacher and other outside sources.

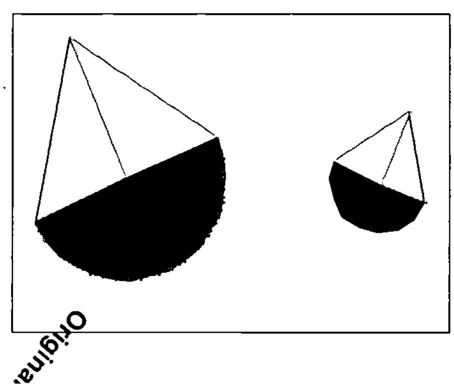
Students in both groups were requested to journal in their electronic diary and to write reflections in response to specific teacher generated questions.

Results

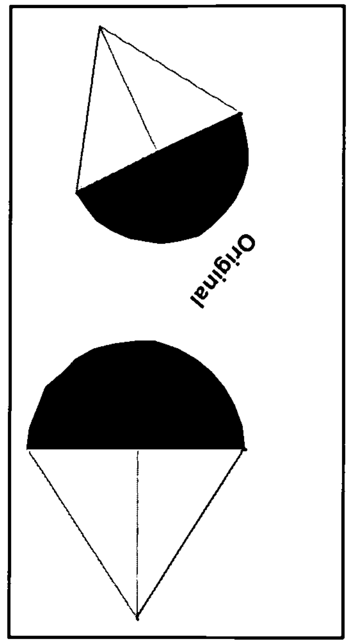
To answer the first question related to whether the instructional approach influenced the students' conceptual understanding of transformations, the students' responses to an assessment created in Geometer's Sketchpad was analyzed. Five figure pairs were designed to focus the students' attention on aspects of transformation. Transformations of the translation, rotation, reflection, and dilation types were included. Figure 1 displays three of the object pairs presented to the students for the identification of transformations. Pair A was constructed using one transformation, Pair B was constructed using two transformations, and Pair C was constructed using three transformations. Students were requested to identify the transformations required to go from the first object in the pair to the second. A score for each collaborative group was calculated to be the sum of the individual group members. The mean group score was 5.25 for the teacher-structured problem solving group and 3.75 for the student-directed problem solving group. This difference indicated that the students who were in the teacher-directed group seemed to have a better understanding of the transformation concepts.



Pair A. Rotation



Pair B. Reflection and



Pair C. Reflection, rotation, and

Figure 1. Transformation Assessment Pairs

A content analysis of the students' journals was conducted to assess the their perceptions of the support provided by the instructor, challenges, frustrations, and successes while working on the project-based learning activities. A constant-comparative method of analysis was applied to identify patterns and themes within and between the groups. The journal entries generated by students in the self-directed groups were compared with those of the students in the teacher-facilitated groups. The goal of this analysis was to explore the students' motivational states and experiences while they were engaged in the use of Geometer's Sketchpad to complete a project-based learning activity. Motivation to succeed in mathematics and the sense of one's ability to do so was of interest in this study given the all-girls school population. It was believed that the girls' sense of self-efficacy could be derived from this data.

The prominent theme of their journals was the frustration they experienced while working with Sketchpad. Students in the self-directed groups expressed higher levels of frustration when trying to develop strategies to apply transformations to their constructions. The students in the teacher-directed groups had a better sense of what strategies should be used, but expressed frustration when errors in the process of applying transformation procedures. In their journaling related to the support provided by the instructor differences in their perceptions were revealed. The students in the teacher-directed groups often referred to specific help that they received, whereas the students in the self-directed group commented that their instructor gave them hints and guided them to self-discovered solutions to their problems. This sense of self efficacy was revealed in the following comment:

> The challenges I faced today were trying to figure out how I did what I did yesterday. We had some trouble but finally figured it out! YAY! And the best part is, IT ALL MOVES LIKE ITS SUPPOSED TO! I think I am the happiest girl alive. My new knowledge is that I know how to make a slider work. My success is that WE GOT THE SCALE TO WORK! You helped us figure out what we were doing wrong.

Another journal entry by a student in the self-directed group expressed the following thought:

> Today was very annoying. My computer crashed yesterday and it didn't allow me to back up, so therefore, my group and I had to start from scratch. However, it did not take long to catch back up. We knew exactly what we had to do and we got it done. We worked hard and didn't even ask Mr. Thomas for help. I believe this shows that we know what we are doing to the point that we are comfortable enough with our project that we can do it on our own. I'm feeling good about this project!

Additionally, while one of the researchers was the instructor for the course the other researcher conducted observations during the class sessions. The observations revealed distinct differences between the two groups in the process of task completion. In the unstructured model, distinct roles of group members were observed. Usually, one girl assumed the role of "Sketchpad expert" and worked independently to complete the geometric design. The other group members assumed other roles and worked independently to complete their tasks. In contrast in the teacher-facilitated model, the students collaborated to complete task activities. An example of a scaled construction representing a garden design is displayed in Figure 2.

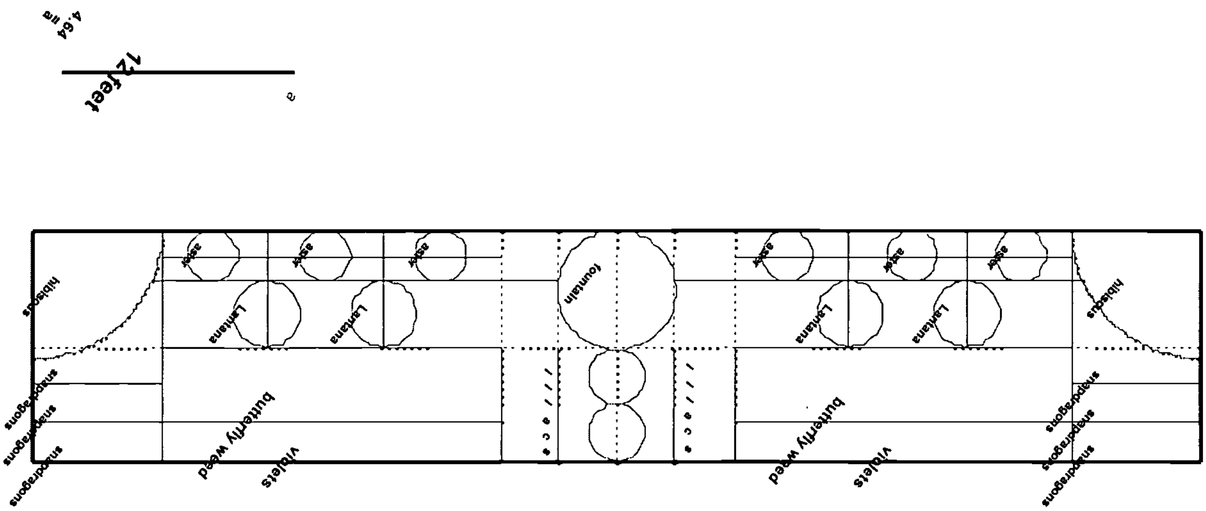


Figure 2. Scaled Construction

Discussion

Examining the effect of varying levels of instructional guidance and the role that the teacher plays when implementing these instructional strategies provides information to teachers who are current or potential users of this type of learning environment. In general, in the short term, the instructional model where the teacher provided structure and directed the problem solving activities of the students resulted in learner outcomes characterized by greater understanding of the concepts and less frustration with the process of using Sketchpad. However, many students in the self-directed group expressed a sense of self–confidence and pleasure with their accomplishments. At the presentation, samples of the scaled constructions created by the students in both groups will be demonstrated. Additionally, insights about how young women respond to the various instructional strategies will be provided. The National

Council of Teachers of Mathematics' (2000) equity principle holds that "excellence in mathematics education requires equity-high expectations and strong support for all students" (p. 12). Given that there still remain substantial gender inequities in the success that is achieved in mathematics (Bielinski & Davison, 1998), another important result derived from this research is how models of instruction support the achievement of women in mathematics.

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