Findings Abstract

The Effects of Using a Dynamic Geometry Software Program on the Learning of Geometric Constructions in an Eighth Grade Mathematics Class

Carol Hodanbosi, Ph.D., NASA Glenn Research Center

This study has attempted to examine a variety of aspects that are associated with the use of dynamic software in a mathematics classroom. It clearly demonstrates the instructional effectiveness of Geometers' Sketchpad as compared to the use of traditional construction tools. Being able to click with the use of a mouse and change the measurements of angles and segments helped the students to remember the results better than students who used a ruler and protractor to draw and redraw the same angles and segments. There are a number of reasons for this result. The reasons that are addressed are the novelty of the software and computers, the automaticity that the software provided, the visual aspect that the software provided, the interactivity of the software, and the ease of experimentation. First of all, one influence was the novelty aspect regarding the use of a different type of mathematics software and the use of computers as a normal part of the classroom lesson. Although the eighth-grade mathematics classes at this school had previous exposure to various types of mathematics software and the computer laboratory as part of their mathematics class, it was generally used apart from the regular mathematics curriculum. The computer lab was used for special project assignments, such as using a spreadsheet to plan a party or create a budget. If particular software programs were used, they were of the types that used logic or numeric games to provide practice in computational skills. The software tool used in this project was of a type that most, if not all, had not been exposed to previously. For the SG the computer lab was their classroom for three weeks, instead of just one or two days at a time. The software and the lessons derived from the software were directly tied into their classroom learning and covered topics that were new to them. They had not been previously involved in any similar program in their mathematics classes. The second reason that the software proved to be a more effective tool than the construction tools was the obvious nature of its automaticity. The software program had several tools and operations that were automated, making the use of the software very efficient. The various measures that the software could determine illustrate part of its flexibility. The software program automatically calculated the measures of angles, sides, areas, and perimeters. In addition, as the drawings of the angles, sides, areas, or perimeters were stretched or shrunk by the user, the measurements changed in real-time. This ties into a visual aspect that is discussed in the next paragraph, in which the deliberate changes made by the users caused a resulting change in the numerical measurement. The cause and effect relationship that this software provided gave the opportunity for students to make conjectures based on their observations. For example, when students had to determine in a triangle the relationship of the lengths of sides to the angle opposite the side, they were able to expand the size of the angle automatically and observe the resulting change of the opposite side, assisting them visually. A second automated tool that the students used in this project was to recreate constructions automatically. For example, after the students created an equilateral triangle using a particular construction process, they could choose to automate this by recording the process. The sequence of constructions and measurements would be duplicated on a different segment length on a different screen. The educational merits of this are discussed later. Another important aspect of this feature was that it was not as dependent on the dexterity of the student as the use of construction tools. There were several instances when the students in the tools group became frustrated using the compass, especially when drawing circles. Although there were no physically handicapped students in this project, it could be an important factor for using the software over the construction tools for those individuals that have coordination difficulties. Thirdly, the visual demonstrations that were provided by the software and the accompanying lessons were more effective visually than the printed page. The ability to clearly visualize geometric models is an important first step in the problem solving process. According to Weaver and Quinn, it helps them understand what the problem is asking (1999). The computer screen displayed figures formed by the software program that could be altered, measured, moved, stretched, and shrunk. The students could see these changes while they were making them. If a mistake was made in the manipulation, it was also clearly seen and understood by the user. The construction tools group drew their figures on a piece of white paper. It was not possible for them to move the figures without moving the paper, unless they erased them and redrew them. After several mistakes, the paper sometimes became damaged and darker in color, so that it was difficult to see the figures. Because they were not as coordinated with the use of compasses and pencils as a more experienced person may be, this happened frequently in the tools group. The interactive nature of the software relates to the visual component that was discussed in the previous paragraph. It is difficult to separate the two, since they rely so heavily on the visual learning process. As previously stated, manipulatives are physical objects that are used in the mathematics classroom to assist visually in the development of the understanding of abstract concepts, and much research supports their use (Behr, 1976; Branch, 1973; Kennedy, 1986; Reys, 1971). They serve as useful modeling tools to assist the teacher in the representation of abstract ideas (NCTM, 1991). For example, sheets of transparent plastic can be used as manipulatives to represent planes, whereas sticks or rulers can be used to model lines and segments. These tools provide a visual representation of geometric ideas that help the students to understand how these ideas relate to each other. The models are somewhat limited, however, because they do not have all of the characteristics of the idea they are used to model. Since a sheet of transparent plastic has a definite length, width, and thickness, unlike a true plane, many students are confused when it is used to represent a plane. It is difficult for them to think in abstract terms of "infinite length" or "infinite width" because these terms have no relationship to the students' real world. A line or a ray that is drawn on the computer screen with this software does continue as far as they are able to scroll on the screen. There are no other limitations. It seems apparent that the interactive component of the geometry software used in this project not only replaces the need for standard manipulatives, but surpasses them. Another example of the benefits of the software is that students can construct or observe previously constructed special triangles, such as isosceles triangles, to determine whether it is possible for a constructed isosceles triangle to have an obtuse angle. By clicking on any vertex of the triangle, the student can change the size of the angles without altering the isosceles characteristic of having two congruent sides. As the students change the size of a particular angle, the number indicating the angles measure of degrees subsequently changes and can be easily observed. It allows the student to look at many special cases and several examples in a minimal amount of time. This interactive nature of the software provides an instant visual feedback, an important feature that is not available when a student has to stop and measure several angles when using a protractor, paper, and pencil. The student who is confined to the use of paper and protractor to measure several examples, and, while doing this, to also concentrate on the correct way to measure an angle, may be misdirected from the original conjecture of what he or she was trying to do. This is especially true for novices that are learning several new situations concurrently. An example of the effectiveness of Geometers' Sketchpad over the use of construction tools was demonstrated in one of the lessons to which the students were given. The students were shown a triangle with all measurements of angles and segments provided. The students were to observe the measurements as they clicked on the vertex angle of the triangle and moving the point around. As they did so, the measurement values changed also. The students were asked to compare the relationship of the size of the angles with the length of the side opposite the angle. This can be a difficult concept for the students to grasp on their own, but the continual and immediate visual feedback allowed by the software helped to foster their understanding. This was supported by studies of Choi (1996), Lester (1996), Clements and Battista (1994), and Yerushalmy and Chazan (1993). Their research suggested that the usefulness of the dynamic software tool depended not only on its efficiency, but also its ability to enhance the user's ability to visualize relationships. The software provided an easy way to allow for experimentation and conjecturing. One student, the low ability male, answered in the Personal Interview Questionnaire when asked what differences he noticed between the hands-on tools and the software program, that “the computers let you experiment first.” In order to explore, however, they must first be given a chance to explore. One of the important features of Geometers' Sketchpad was that it facilitates the testing and making of conjectures (Clements & Battista, 1994). When students observed the changing of a vertex angle in a particular type of triangle, perhaps attempting to see if it is possible for an isosceles triangle to have a right angle or an obtuse angle, they can make generalizations based on their observations. Because of the efficiency of the software program, students were able to draw far more diagrams, and more accurately, to support a generalization than would be possible using traditional construction tools. These generalizations were performed in a self-directed learning type of environment. The software, along with the technology of the desktop computers, provided a one-to-one discovery, yet guided, process that allows students to model and explore. In the past, students have accepted the textbook classifications because it would take too much time to explore, to make tables, to conjecture, and to make sure that all possible cases would be investigated. The use of this software provided a way for this to happen without using a large amount of class time and would also give the students experience in the dynamics of the exploration process. Having students share in the exploration and conjecturing process will increase their involvement and participation in the mathematics classroom. A second important finding of this study was that the eighth-grade males had a significantly higher attitude toward mathematics than the females. This feature corresponds with much of the research findings regarding gender differences in attitude toward mathematics. Aiken's (1970) meta-analysis found that although the most influential years of formation of attitude toward mathematics were between the fourth and sixth grades, there was also a high amount of negative attitudes during the middle grades. Many researchers (Aiken, 1970; Paulsen & Johnson, 1983; Schofield, 1982; Thorndike-Christ, 1991; Tsai & Walberg, 1983) supported the idea that males have a more positive attitude toward mathematics than females. According to their research, this difference begins in the late elementary grades and continues throughout high school. Other researchers have found that gender differences begin in early adolescence (Hyde et al., 1990, 1995), with the males having more positive attitudes than the females. The third finding, that the higher-ability mathematics students out-performed the lower ability mathematics students, regardless of treatment and gender, was an expected result. Students of high ability levels generally out-perform low ability students on achievement tests. These same results were found by research conducted by Petersen and Kellam (1977) and Hong (1999). In Hong's study, the difference in the overall means of the achievement test scores was significantly different, with the low ability students having a mean of 27.5, and the high ability students having a mean of 34.4. These results, paired with the information that the ability level of the students did not have a significant effect on their attitude toward mathematics, seem to reinforce the data from this research and other studies that indicate a low correlation between attitude and achievement.