Effects of Computer Animation on Spatial Visualization Skills

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Abstract

Animation improves spatial visualization according to many researchers. The purpose of this study was to determine the effects of a sixteen-week long animation class on spatial visualization performance. The students in the treatment group were provided instruction consisting of four hours of lecture/lab each week. Lecture/Lab consisted of lessons on the fundamentals, history, and techniques of animation. The students were provided instruction in and opportunity to use three different animation packages (Flash ®, TrueSpace ®, and 3D Studio Max ®). The spatial visualization performance of the students in the animation group was compared to a control group of students in a Foundations of Graphics (GC120) class. Using the data collected a paired T-test was completed on each group to determine progress made within each group. To test which group made the most improvement an Independent Samples T-test was used to make the comparison between the animation test group and the control group.

Introduction

The purpose of this study was to investigate the effects of using computer animation as a tool for improving spatial visualization performance in college students. The researcher investigated whether the use of computer animation and computerized modules of instruction can produce beneficial results on the understanding and improvement of spatial visualization abilities. The results of this study are expected to be important in the advancement of the use of computer animation in teaching.

Animation is capable of providing both real and apparent motion which adds realism which results in improved viewer perceptions of the relations between objects [Blake, 1]. Computer animation takes advantage of its ability to provide meaning, to illustrate, and to give organization to the material being taught [Klein, 13; Profit & Kaiser, 16]; therefore, animation is used in many fields of study [Bodner & Guay, 2; Strong & Smith, 21].

Research on animation includes work that has compared animation to still images, text only, still images with text, and motion pictures (video). Prior to the current standards of computer animation, motion pictures were consider by some researchers as "far superior" compared to still images with or with text [Caraballo, 6; Klein, 13; Shubbar, 19]. Bush and Gresham [5] found consistent increases in the amount trainees learned when the learning situation included animation. Animated visuals allowed better retention in student learning and communicated ideas involving time and space better than text [Hays, 11; Mayton, 15].

Viewer controlled animation provides significantly improved depth perception and increases conceptual ideas through the development of mental models [Williamson & Abraham, 24; Wiley, 23]. Additionally, viewer-controlled animation leads to improvement in cognitive, perceptual, and motor skills and allows the creation of a three-dimensional simulated world in which spatial performance can be developed, assisting in anchoring the student into reality for the use of visual objects [Johns & Brander, 12].

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Target Population

The target population for this study is students in fields that require visualization skills for the mental manipulation of three dimensional objects. Professions in chemistry, mathematics, various fields in engineering, and technical graphics are the primary target groups considered for this study. This research, however, could be applied to the general population in any area that has an interest in or requires improved spatial visualization.

Research Design

Since the researcher collected the data from two intact classes, this study used a nonequivalent control-group design (Table 1). The purpose of selecting this design was to maximize the likelihood that measured differences between the experimental and control groups would reflect the actual differences. When conducted properly, this type of research design can control the following threats to internal validity: maturation, history, instrumentation, testing, statistical regression, and experimental mortality [Gall, Gall, & Borg, 7].

Table 1. Research Design

Group	Pretest	Treatment	Posttest
1- Animation (experimental)	O1	X1	O2
2- Technical Graphics (control)	O1	X2	O2

Key

Group – 1- experimental, group2 - control, Nominal level

Score – O1-score on pretest, O2-score on posttest, Interval level

Treatment – X1 – treatment for experimental group , X2 – treatment provided to control group

X1 – 16 week course in animation

X2 – 16 week course in technical graphics

Method

In order to develop animation tools that improve spatial visualization, previously developed tests have been used as measurement instruments. These tests have been developed and validated over time and usage. The list of tests include the Revised Minnesota Paper Form Board [Likert & Quasha, 14], the S-M mental rotations test [Shepard & Metzler, 18] later revised by Vandenberg and Kuse [22], The Purdue Spatial Visualization Test (a series of three tests) developed by Guay [8] and later experimentally modified by Branoff [3, 4] with coordinate axes added and a molecular rotations test developed by Seddon, Eniaiyeju, and Chia [17] that was later translated to English by Shubbar [19]. Of these tests the Visualization of Rotations portion of the Purdue Spatial Visualization Test was deemed the best test for measuring spatial visualization performance [Guay & McDaniel, 10, Sorby, 20].

The Purdue Spatial Visualization Test, designed by Guay [8], is a series of items that includes three different tasks to test spatial ability. This research used the Purdue Spatial Visualization Test – Visualization of Rotations (PSVT:R). The test contains thirty test items. Each test item provides an example set of figures and a test set of figures. The example set shows a new figure before and after it has been rotated about one or more axes.

In previous evaluations of this test, a correlation of 0.61 was obtained when compared to the Sheppard-Metzler test [Guay, 9; Bodner & Guay, 2]. The first three studies to use the PSVT:R had a total of 217 university students. The reliability of the internal consistency coefficients was .87, .89, and .92 (Guay, 1980). Additional studies have indicated the validity of the PSVT:R [Guay & McDaniel, 10, Bodner & Guay, 2].

Each class took the PSVT:R as a pre-test during the second week of the semester. This helped to eliminate students that dropped the classes in the first week. The posttest was administered during the last week of classes. The researcher administered the pretests and posttests to both groups in the study.

Sample

The sample groups used in this study were composed of students from two classes taught at NCSU. The groups varied in size due to equipment and software limitations. Both classes were taught in the fall semester of 2001. The choice of this population was made for practical considerations that involved the availability of subjects, the willingness of their instructor to participate, and cooperativeness of the students to work with the educational research efforts of the university.

Group 1 – Animation (Experimental Group)

The animation class has no pre-requisites and is open to all students. The class started with sixteen students and finished with thirteen students. At the beginning of the semester, the class consisted of two females and fourteen males. By the end of the semester, three of the males had dropped out. The females in the class had no previous experience in technical graphics. One female was concurrently enrolled in a Foundations of Graphics class and as a consequence was eliminated from the study. All of the male students in the class had previously taken several of the technical graphics courses, and many of them had work experience in the technical graphics area. Four of the students in this class were Technology Education majors and seven were Graphic Communications majors. The only exception was the female who was a design major. The age of the students in this group ranged from twenty-four to twenty-nine and one student was forty-two. The final group sample size was N=12.

Group 2 – Technical Graphics (Control Group)

The Foundations of Graphics class is an introductory class in the technical graphics area and has no pre-requisites and is open to all students. The emphasis of this class is to provide an orientation to the language of engineering graphics. This includes a knowledge base of the various types of drawings (perspective and parallel projections) with emphasis on the principles of orthographic projections (multiview), the need for sections and auxiliary drawings, and dimensioning and tolerancing standards, plus visualization techniques. Additional work is focused on the Concurrent Engineering Design Model. The principles learned are applied using a software package to produce a final project for the class.

The students in group 2 ranged from eighteen to thirty-one years of age. The class started with twenty-four students but through attrition class size was reduced to nineteen (19) students by the end of the semester. The final student makeup for group 2 was 6 females and 14 males. These students were primarily electrical engineering, civil engineering, and mechanical engineering majors who were taking the class as a general education elective. The balance of the group consisted of a Technology Education major and a Psychology major. The former was required to take the class and the latter was taking the class as an elective. The final group sample size was N=19.

Research Questions and Hypothesis

To study the possibility of improving spatial visualization skills, the investigation asked the following questions:

1. Will instruction in a sixteen week computer animation course (group 1) significantly improve spatial visualization performance in undergraduate students?

2. Will instruction in a sixteen week basic technical graphics (group 2) significantly improve spatial visualization performance in undergraduate students?

3. Will instruction in a computer animation course (group 1) provide higher scores indicating a higher development of spatial visualization than basic a technical graphics course (group 2)?

Questions 1 and 2 were answered by using a difference in means test between pretest and posttest scores on the Purdue Spatial Visualization Test – Visualization of Rotations (PSVT:R) collected at the beginning and end of the sixteen week instruction period. The hypotheses for questions 1 and 2 were:

$H1_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2).

$H2_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take the Foundations of Graphics class (Group 2).

Procedures

The purpose of this study was to determine whether instruction in technical animation improves spatial visualization in undergraduate students more than instruction in technical graphics. A sample of 31 students was used as a control and experimental group. Each group took the PSVT:R as a pre-test and posttest. Analysis to test for improvement within each group used a paired samples T-test (small sample) for a difference in means between the pretest and posttest scores. The test used for analysis between the groups was an independent sample T-test for a difference in means between the posttest score of groups 1 and 2.

The sample groups were administered the thirty question PSVT:R as a pretest during the second week of a sixteen week class in either animation (group 1) or in a beginning technical graphics class (group 2).

The treatment for group 1 (experimental) was the normal course work and instruction in three different animation packages. The instruction included the history, terms and techniques used in animation. Instruction in Flash ® (a two-dimensional animation package), TrueSpace ® (a three-dimensional gaming animation package), and 3D Studios Max ® (a professional quality animation package) was also provided. The students were required to complete a project using each of the animation packages. The projects consisted of simple animation actions for Flash ®, an animation of a cross sectional view of an internal combustion engine. In TrueSpace ®, objects were required to roll off a table top and bounce realistically on the floor. Primary emphasis was placed on 3D Studio Max ® in which the students were required to create a one minute animation on any technical subject of their choosing.

The treatment provided to group 2 (control) was that of the normal instruction and assignments for the Foundations of Graphics classes. Instruction included the topics of sketching, geometric relationships, multiview sketching, isometric sketching, dimensioning practices, and section and auxiliary views. Instruction in AutoCAD ® was also provided to acquaint the students with CAD applications. The students in group 2 were required to learn how to use the AutoCAD ® program by completing provided tutorials and completing two major projects that allowed the students to demonstrate their competency in technical graphic fundamentals and AutoCAD ®.

A posttest was administered to each class during the last week of class. The students were not provided with scores from the pretest and were encouraged to do their best. The researcher administered the pretest and post test to both of the sample groups. The instructions from the PSVT:R were read to the students prior to the start of the test and no other form of instruction was given. All groups received the same instructions. Scores for students that took the pretest but not the posttest were removed from the sample group to prevent skewing of the results of mean calculations.

The pretest and posttest scores collected were used to perform comparisons within each group to determine if any significant difference existed in the before and after test scores or between the groups in the posttest scores. The researcher taught the students in the technical graphics group. Dr. A. Clark taught the students in the animation group.

Utilizing the data collected from the classes, the groups (technical graphics or animation) were analyzed by performing a paired sample T-test for questions 1 and 2 and an independent samples T-test for a difference in means for question 3. Table 2 provides the pretest/posttest mean scores with standard deviation obtained on the PSVT:R for both the control and experimental groups as seen in questions 1 and 2.

Table 2. Pretest and Posttest Scores by Treatment Group

	Control Group		Experimental Group	
Variable	Mean	Std Dev	Mean	Std Dev
Pretest	24.631	3.804	24.583	4.452
Posttest	24.947	4.249	25.083	3.965

Question 1

To investigate question 1, will training in computer animation significantly improve spatial visualization performance, the data collected for Group 1 (animation group) will be analyzed using the following hypothesis.

> $H1_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 1).
>
> $H1_A$ – There will be a significant increase between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 1).

The results of the paired sample T-test using the pretest and posttest for the Experimental group are given in Table 3. As shown the analysis failed to reveal a significant difference between the pretest and posttest groups. A T-score of 0.460 and a corresponding p value of 0.658 indicate that there is no significant difference between the pretest and post test score on the PVST:R for the Animation (experimental) group. Thus the analysis of the data leads to the conclusion that the null hypothesis cannot be rejected for Question 1.

Table 3. Analysis of Mean Gain Scores for the Experimental Group

Variable	N	Mean	Std Error	T	Pr > |T|
Diff	12	0.500	1.098	0.460	0.658

Question 2

To investigate question 2, will training in a Foundations of Graphics significantly improve spatial visualization performance, the data collected for Group2 and the second hypothesis will be used.

> $H2_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a Foundations of graphics class (Group 2).
>
> $H2_A$ – There will be significant increase between the pre-test scores and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a Foundations of graphics class (Group 2).

The results of the paired sample T-test using the pre-test and posttest for the Control group are given in Table 4. As shown, this analysis failed to reveal a significant difference between the two groups (pre-test and posttest), a t-score of 0.440 with a corresponding p-value of 0.669. The analysis of the data leads to the conclusion that the null hypothesis cannot be rejected for Question 2.

Table 4. Analysis of Mean Gain Scores for the Control Group

Variable	N	Mean	Std Error	T	Pr > |T|
Diff	19	0.316	0.726	0.440	0.669

Question 3

Investigation of question 3, will training in computer animation provide higher average scores on the PSVT:R than the Foundations of Graphics class and introduction to engineering graphics class, will be completed by using the data collected for the graphics group and the animation group and hypothesis 3.

> $H3_N$ – There will be no significant difference between the posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 1 – Treatment) and students who take the Foundations of Graphics class or introduction to engineering graphics class (Group 2 – Control). G1 = G2

> $H3_A$ – There will be a significant difference between the posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 1) and students who take the Foundations of Graphics class or introduction to engineering graphics class (Group 2). G1 ≠ G2

The independent samples T-test conducted compared the animation group posttest score to the average posttest score made by the graphics group (G1=G2). The data in Table 5 indicates that the difference in means test resulted in a t-score of 0.09 with a corresponding p-value of 0.929. The high p-value would indicate that no significant difference existed between the groups. Analysis indicates sufficient evidence to support the null hypothesis. Additionally, a test on variation was made by the statistical software; this test indicated that there was no significant difference between the variations of the posttest scores.

Table 5. Analysis of Posttest Scores between Treatment Groups

Variable	DF	T	Pr > |T|
Posttest	24.8	0.090	0.929

Analyses

Question 1 – Will instruction in a sixteen week computer animation class (group 1) significantly improve spatial visualization scores on the Purdue Spatial Visualizations Test – Visualization of Rotations? It was hypothesized that there would be no significant difference between the pretest – posttest scores on the PSVT:R for the treatment group. Analysis using a paired samples T-test between the pretest/posttest indicated there was no significant difference in scores between the pretest and posttest ($t = 0.30$, $p = 0.7698$). The failure to reject the null hypothesis indicated there was no significant difference between the pretest and posttest scores on the Purdue Spatial Visualizations Test – Visualization of Rotations. This indicates that there was no significant improvement in the spatial visualization scores of the students that took part in the sixteen week animation class. The findings support Null Hypothesis #1.

Question 2 – Will instruction in a sixteen week basic technical graphics class (group 2) significantly improve spatial visualization scores on the Purdue Spatial Visualizations Test – Visualization of Rotations? It was hypothesized that there would be no significant difference between the pretest – posttest scores on the PSVT:R for the treatment group. Analysis using a paired samples T-test between the pretest/posttest indicated there was no significant difference in scores between the pretest and posttest ($t = 0.44$, $p = 0.6686$). The failure to reject the null hypothesis indicated there was no significant difference between the pretest and posttest scores on the Purdue Spatial Visualizations Test – Visualization of Rotations for the technical graphics group. This indicates that there was no significant improvement in the spatial visualization scores of the students that took part in the sixteen week technical graphics class. The findings support Null Hypothesis #2.

Question 3 – Will training in a sixteen week computer animation class (group 1) provide higher scores on the Purdue Spatial Visualizations Test – Visualization of Rotations than instruction in a sixteen week basic technical graphics class (group 2)? It was hypothesized that there would be no significant difference between the posttest scores on the PSVT:R for the animation and the technical graphics groups. Analysis using an independent samples T-test between the posttest scores of the test groups indicated there was no significant difference in scores between the posttest of each group ($t = 0.09$, $p = 0.929$). The failure to reject the null hypothesis indicated there was no significant difference between the posttest scores on the Purdue Spatial Visualizations Test – Visualization of Rotations for the animation and technical graphics groups. The findings support Null Hypothesis #3.

Conclusions and Discussion

Although the results of this study cannot be generalized to populations other than the ones that are similar to those that were used in this study, the results indicated the following:

1. The students in the animation group did not significantly improve their spatial visualization. A possible explanation for the lack of significant improvement is that the spatial visualization ability of these students was previously developed and that no further improvement in scores could be measured with the PSVT:R.

2. The students in the technical graphics class did not significantly improve their spatial visualization. A possible explanation for the lack of significant improvement is that the spatial visualization ability of these students was previously developed and that no further improvement in scores could be measured with the PSVT:R.

3. The lack of significant difference in spatial visualization performance between the test groups is surprising. It had been noted that animation should improve spatial visualization performance.

Based on the results, the following explanations could be made. The first of these is that animation does not have any significant effects on spatial visualization performance. Animation may only provide motion cues and not really provide the necessary information for the visualization of spatial relationships. Secondly, significant improvement in spatial visualization of these students could not be measured with the PSVT:R, and a different test instrument should have been used. The change in spatial visualization ability may have been too small for the instrument to measure. It may well be necessary to use a combination of instruments to measure the change in spatial visualization. A third possible explanation is that there was no real improvement in either of the test groups so no difference existed. The level of spatial visualization may have already been developed by the students' life experiences. A fourth possible cause for no difference is the instruction provided to the test groups. The instruction provided to the students may have only improved technical skills and not been geared towards improving spatial visualization skills. Additionally, students in engineering and technical majors are suspected of having developed spatial visualization skills through previous life experiences. That ability would tend to attract students to the engineering and technical fields of study. Finally, it is possible that a single course in animation is not sufficient to improve spatial visualization.

The biggest factor affecting the results of this research is the small size of the sample. This study is inconclusive due to the limited sample size and should be completed with a larger sample and a different instrument or combination of instruments to measure the spatial visualization of the students.

Implications for Teaching

Educators in technical animation and engineering and technical graphic should consider the results of this study before integrating animation activities into the curriculum if the sole purpose is to increase spatial visualization over the course of one semester. It appears that neither instruction in animation nor technical graphics had any significant effects on students' spatial visualization ability as measured by the PSVT:R. Teachers should use animation to some extent in classroom activities if the opportunity presents itself. Student exposure to animation should only enhance the learning experience by providing the student with new knowledge and experience.

Recommendations for Future Research

The results of this research suggest that further study in the area of spatial visualization be conducted. The significance of spatial visualization performance has been noted from many sources and indicated throughout this research. The need to find the best method or combination of methods to assist the student in learning and improving his/her spatial visualization is paramount. This research should be redone using a larger sample size and should include samples from other learning institutions (secondary and post-secondary). As new technology is made available, this work should be completed again to determine whether more improvement in student spatial visualization can be accomplished.

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