Multiview Drawing Instruction: A Two-location Experiment

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ABSTRACT

Several methods have been developed, presented, and discussed at recent ASEE and EDGD conferences on the topic of computer-based multiview drawing instruction. While small-scale and localized testing of these instruments and methods has been undertaken, no larger-scale or multi-location experiments have been attempted. This paper describes an experiment that was carried out at two different university campuses with engineering and non-engineering students in an effort to validate the efficacy of these tools in comparison with more traditional methods of orthographic drawing instruction.

Students at each location were assigned to one of four groups and asked to use either one of two computer-based instructional tools, a mixture of computer and manual methods, or an entirely manual method of multiview drawing instruction. Through the use of pre-test/post-test data and survey information, student scores and perceptions were analyzed for useful quantitative and qualitative results. The results have implications for foundational instruction, self-study, and remediation of students in engineering graphics and other fields where spatial skills are important.

INTRODUCTION

As has been described in past studies, a significant challenge that many engineering and technology students struggle with is the ability to imagine a three-dimensional object from different perspectives and therefore recognize and draw that object in two dimensions (Connolly & Maicher, 2003; Maicher & Connolly, 2003). Future success as a student and as a professional in many areas, both technical and non-technical, can be dependent on this ability to manipulate 3D space and utilize mental imagery (Deno, 1995; Holliday-Darr, et al, 2000; Study, 2004). Research in this field has shown that these spatial capabilities can be strengthened through appropriate instruction (Miller, 1996; Sorby, 1999; Sorby, 2001). A useful and applicable method of instruction and practice for engineering and technology students' spatial skills has traditionally involved orthographic/multiview drawing.

There are several problems that must be overcome for multiview drawing to be effectively used as an instructional tool. First, it is important for students to comprehend the basics of multiview drawing, and master the fundamental concepts of multiview drawing applications. Second, the instructor must be able to deal with a wide variety of visualization abilities in the students, and deal with the logistical issues of providing instruction and feedback to students participating at these various levels of ability and experience.

The use of computer-based instruction is one method of dealing with the difficulties mentioned above. Computer-based instruction allows for self-paced and varied emphasis lessons, practice, and remediation, providing the instructor much flexibility in such situations (Newby, et al, 2000; Alessi & Trollip, 2001; Eom & Reiser, 2000). The goals of the current study were to investigate the feasibility and effectiveness of several methods of multiview instruction. In addition, we investigated whether the tools were equally effective when used by women and men and by less experienced students such as education majors in comparison to engineering majors. The advantage of a multi-location study is that difference populations can be more efficiently combined and compared.

METHODOLOGY

Research was carried out at two locations: Penn State Erie, The Behrend College and Purdue University. In each setting, groups were randomly assigned to one of four instructional conditions. One group underwent multiview instruction and practice exercises using Introduction to 3D Visualization software developed by Sheryl Sorby of Michigan Technological University. A second group experienced multiview instruction using Multiview Drawing software developed by the first author and Kellen Maicher at Purdue University, followed by standard paper-and-pencil practice. A third group was exposed to the same Purdue Multiview Drawing software followed by computer-based practice software called Interactive Multiview Drawing, also developed Connolly and Maicher at Purdue. The final group was the non-treatment group that experienced standard lecture instruction on the multiview topic.

PARTICIPANTS

The Purdue University participants consisted of 16 male and 29 female (n= 45) students enrolled in a Technology in Education class. These students were education majors, and with a few exceptions, had no prior experience in engineering drawing principles.

The Penn State Behrend participants consisted of 69 male and 8 female (n = 77) students enrolled in BDENG 100S, Introduction to Engineering Design. One credit of this three credit course is devoted to learning Word, Excel, sketching, and CAD. Students were from a variety of engineering majors with a mixture of previous engineering drawing principles exposure.

INSTRUMENTS

There were four instruments used in this study, including a multiview drawing pre-test and post-test, Introduction to 3D Visualization software (Sorby) containing orthographic lessons and practice problems, Multiview Drawing instructional software and Interactive Multiview Drawing computer sketching software (Connolly, Maicher), and a spatial experience questionnaire.

The pre-test and post-test consisted of fifteen problems each, wherein the participants were asked to look at an isometric pictorial representation of an object and then select from three options the correct representation of the front, top, or right side view of the object.

The instructional lessons covered all basic principles of orthographic construction and its applications. The Introduction to 3D Visualization software covered other topics as well, but these were not utilized as part of this study.

PROCEDURES

Due to the different structure of classes and characteristics of the participant sample groups, the procedures varied slightly at the two locations.

Penn State Behrend Procedure.

All students enrolled in Introduction to Engineering Design were required to complete a pre-class quiz on a 7 page reading assignment covering the basics of isometrics. A short lecture was given followed by 10 practice problems.

The following week all students were required to complete a pre-class quiz on a 6 page reading assignment covering the basics of orthographics.

- 3-D Vis: Students completed the pre-test, the Background and Exercise portions, which automatically checked their answers, of the Orthographic Drawings section of Introduction to 3D Visualization software, followed by the post-test.
- MV Drw / hand-sketch: Students completed the pre-test, the Multiview Drawing tutorial and test, completed problems using paper and pencil, checked their answers with an answer key, followed by a post-test.
- MV Drw / Interactive MV: Students completed the pre-test, the Multiview Drawing tutorial and test, completed the Interactive Multiview Drawing software, containing the same problems Multiview Drw / hand-sketch group completed by paper and pencil, allowing the students to draw in the software and automatically check their answers, followed by a post-test.
- Lecture / no practice: Students received instruction using traditional methods. The students were given the pre-test, a short traditional lecture on orthographics, followed by the post-test.

Purdue Procedure

Volunteers were recruited out of a technology class for education majors. Several participants had previous experience with multiview drawing. The participants were divided into four groups, with treatments identical to those described in the Penn State Behrend procedure.

There were no pre-class readings or introductory lectures given in the Purdue portion of the study. The Purdue Lecture/practice group did hand-sketch problems for practice.

RESULTS

PURDUE RESULTS

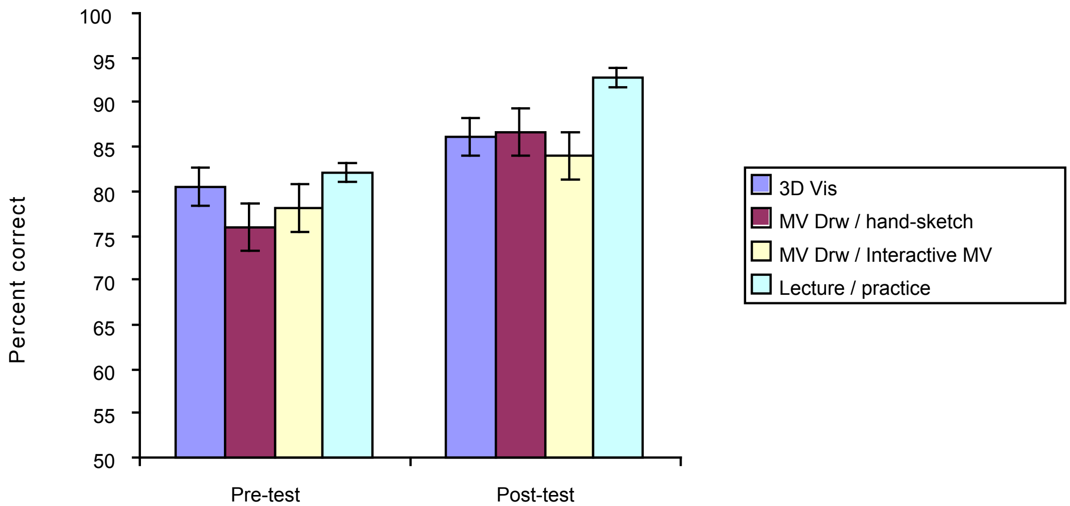
The number of students in each group, mean percent correct, and change scores for Purdue sample are shown in Table 1. All groups showed improvement from the pre-test to post-test.

These scores (percent correct) were analyzed using a 2 (Time: pre-test, post-test) X 4 (Training: 3D Vis, MV Drw/handsketch, MV Drw/Interactive MV, Lecture) mixed ANOVA. The results showed a significant main effect of time with post-test scores significantly higher than pre-test scores, $F(1,41) = 16.01$, $p < .0001$. The main effect of training type did not reach significance $F(3,41) = .67$, $p = .58$, nor did the interaction

Table 1: *Purdue University Results*

Treatment	N	% correct pre-test	% correct post-test	Change
3D Vis	12	80.56%	86.11%	**5.50%**
MV Drw/hand-sketch	10	76.00%	86.67%	**10.67%**
MV Drw/ Interactive MV	10	78.00%	84.00%	**6.00%**
Lecture/practice	13	82.05%	92.82%	**10.77%**

Figure 1: *Average pre-test and post-test percent correct based on training - Purdue*



between time and training $F(3,41) = .49$, $p = .69$. As seen in Figure 1, the results showed that on average, participants improved from pre-test to post-test. However follow-up t-tests comparing each groups pre and post test scores showed that only the lecture group improved significantly $t(12) = 3.51$, $p = .004$; whereas the MV Drw/hand/handsketch group showed a marginal effect that approached significance $t(9) = 2.06$, $p = .07$. It should be noted that the small number of participants limits the power of the current analysis and precluded an analysis by gender. However an examination of mean scores suggested that women tended to show more improvement than men pre-test to post-test.

PENN STATE BEHREND RESULTS

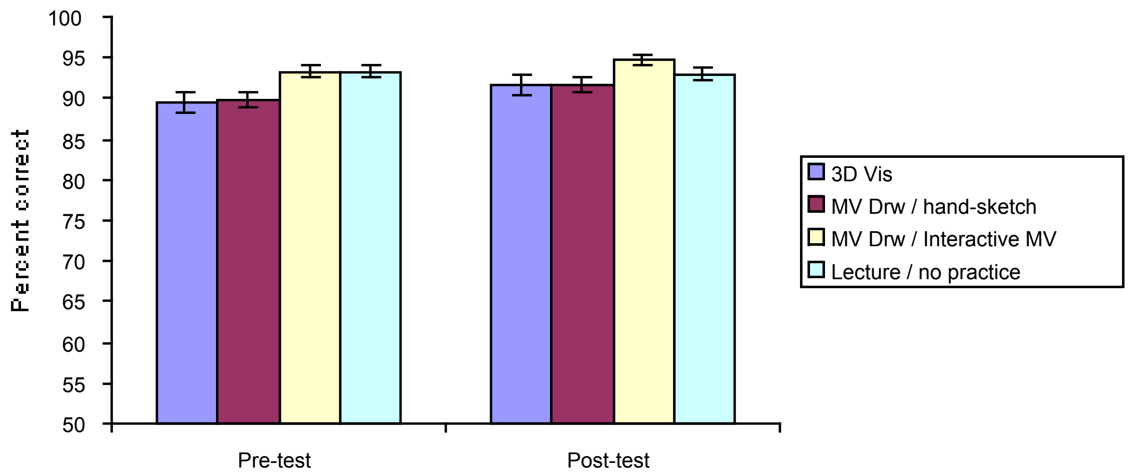
Table 2 shows the N, Mean percent correct and percent change for the Penn State sample. The results of a 2 (time) X 4 (training) ANOVA showed no significant main effect of Time $F(1,73) = 1.729$, $p = .19$. There was also no interaction between time and training, $F(3,73) = .329$, $p = .80$.

Three of the four groups showed a slight improvement from pre to post-test, but follow-up t-tests comparing each group's pre and post test scores showed no significant improvement for any of the Penn State Behrend groups. Figure 2 shows the means and standard errors of percent correct for each type of training in the pre-test and post-test. Note that Penn State sample consisting of

Table 2: *Penn State Behrend Results*

Treatment	N	% correct pre-test	% correct post-test	**Change**
3D Vis	19	89.47%	91.58%	**2.11%**
MV Drw/hand-sketch	21	89.84%	91.75%	**1.90%**
MV Drw/Interactive MV	18	93.33%	94.81%	**1.48%**
Lecture (no practice)	19	93.33%	92.98%	**(0.35%)**

Figure 2: *Average pre-test and post-test percent correct based on training – Penn State*



engineering majors in a graphics class made fewer errors than the Purdue sample, so there may have been ceiling effects in this group.

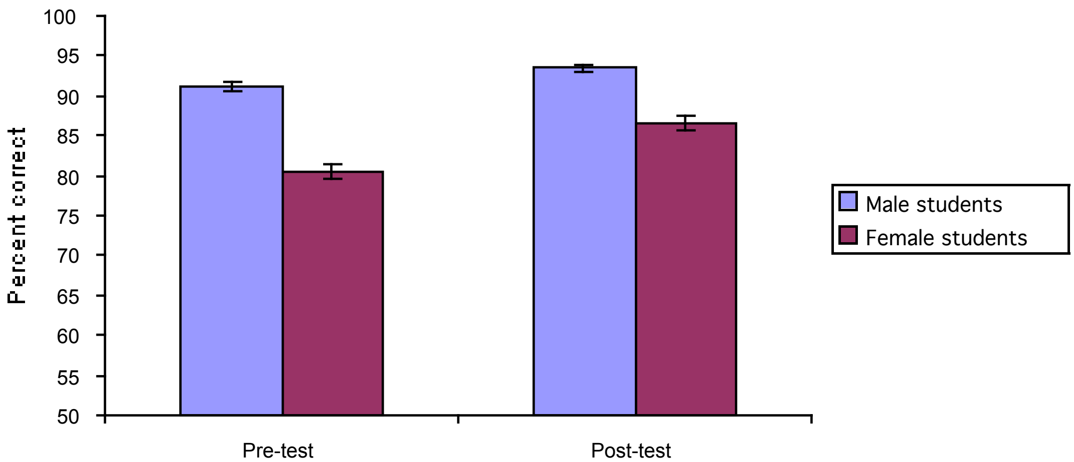
COMBINED RESULTS

In the final analysis we combined data from the two schools to examine the instructional tasks with a larger combined sample giving us more statistical power. This also allowed us to do a sub-analysis comparing men and women that could not be done with the small N in each individual group. These data were analyzed with a 2(time) X 2 (school) X 4 (Training type) mixed ANOVA. The results showed a robust main effect of time with post-test scores significantly higher than pre-test scores, $F(1,114) = 22.27$, $p < .001$. There was also a main effect of school with the Penn State students scoring much higher than the Purdue students. The interaction of time by school was also significant, $F(1,114) = 11.88$, $p < .001$. Follow-up comparisons showed that the interaction was the result of a larger difference between pre and post-test scores for the Purdue students than the Penn State students.

Follow-up comparisons were conducted to examine the effectiveness of each type of instructional method. Because we expected the scores to improve pre-test to post-test we used one-tailed correlated t-tests. The results showed that each of the four methods demonstrated improvement in the larger combined sample. The traditional lecture method and the MV Drw/hand/handsketch techniques reached significance at the more rigorous 2 –tailed criteria ($t[30] = 2.04$, $p = .05$; $t[30] = 2.19$, $p = .042$), while instruction with the 3-D Viz software and the MV Drw/Interactive MV methods reached significance one-tailed ($t[30] = 1.72$, $p = .09$; $t[30] = 1.79$, $p = .08$).

The number of women in the sample was small and this was especially the case in the Penn State sample that consisted of engineering majors, therefore comparisons of the individual methods were not possible, however we did conduct a 2 (time) X 2 (gender) ANOVA to examine whether men and women showed equivalent improvement. Figure 3 shows the mean percent correct for men and women at pre-test and post-test. There was the expected main effect of time, with scores on the post-test higher than the pre-test, $F(1,109) = 14.87$, $p < .001$. But there was also a main effect of gender with men doing better on the task overall, $F(1,109) = 23.74$, $p < .001$. There was also an interaction with time and gender that approached significance, $F(1,109) = 3.19$, $p = .07$. This resulted from the fact that men showed only a 2.3% improvement whereas women showed a 6.2% improvement. This suggests that these

Figure 3: *Average pre-test and post-test percent correct based on gender – combined*



training methods might be even more useful for women who may have lower performance coming into the class.

DISCUSSION

The combined results showed that even a single training session on multiview drawing can produce significant improvement. This improvement is greater for women who at least in the current sample, came to the study with lower skills. The good news is that computerized tutorials which can be standardized and require less instructor involvement in the class, are equally effective to the more traditional instructor led approaches. This could be useful in large schools where instructors of basic courses may be new faculty or graduate students. Of course, developers of these programs would like to see greater effectiveness than traditional approaches. One issue is that any software requires a period of adjustment, so in the current study the effectiveness of the software-based instruction may have been decreased by the time it took to learn to use the software itself. There is some evidence for this in qualitative data. Whereas most students thought the software tools were easy to use, some mentioned that they took time to figure out and in a single class session this could have reduced their effectiveness.

The other issue that the results suggest is that these tools will only be effective if they are used before the students have experience with the concept. For the Purdue students the instruction was probably more effective because by working with education majors, the concepts were less familiar, whereas the Penn State engineering students were more experienced and saw the instruction as a review. These students had very high scores on both the pre and post-tests and some students commented that using the programs involved a lot of work for a relatively easy concept. It is possible that a more challenging pre- and post-test might have reduced the ceiling effects in this group and they would have shown more improvement.

The Purdue sample showed more improvement from the pre-test to the post-test than the Penn State sample. However, one should be cautious about over interpreting the results due to the small sample sizes. One reason for the improvement of the non-engineering students (Purdue) may involve the use of freehand drawing (sketching), either with or without tutorial instruction, as a means of increasing spatial comprehension. The Multiview Drawing/hand-sketch group (10.67% improvement) and the lecture/practice group (10.77% improvement) were exposed to sketching practice problems as part of the treatment, while the Intro to 3D Visualization group and the Multiview Drawing group were not. It is difficult to generalize from these data due to the brief nature of instruction and tutorial exposure, but it is probable that longer duration exposure to the instructional content and media may have a greater impact on the measurable results of the study.

If, as the overall results seem to indicate, the tutorials are similar in effectiveness to traditional teaching methods, the potential use of tools of this nature should continue to be explored in educational settings. Their potential use as remediation aids and for drill and practice could be beneficial in situations where instructors have little time or resources for one-on-one instruction and extra tutoring. Future research should also focus on whether these tools may hold particular benefit for some women students who maybe entering classes with less developed spatial skills, and would have the opportunity to work outside of class.

Multi-location research can play an important role in investigating these questions. The benefits are obvious. Samples can be combined for greater statistical power and the generalizability of the results is enhanced. There is also a downside to these cooperative endeavors. IRB approval must be gained at multiple institutions and it is more difficult to control for potential confounding variables. In our view, these costs are clearly outweighed by the benefits.

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