2006-511: USING REMEDIATION TO IMPROVE VISUALIZATION ABILITIES IN MINORITY ENGINEERING AND TECHNOLOGY STUDENTS

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Using Remediation to Improve Visualization Abilities in Minority Engineering and Technology Students

Introduction

Previous research [1] showed freshman and sophomore Engineering and Technology students enrolled in a two-course series of introductory mechanical drawing and CAD at an HBCU had significantly lower than average test scores on the Purdue Spatial Visualization Test: Visualization of Rotations (PSVT) when it was administered during the first week of class. Although the initial group of students' posttest scores showed some improvement, the mean was still not up to average.

To test a method of improving the students' visualization abilities, one section of the first course in the series, a primarily 2D-focused course, received remediation in a variety of forms and the posttest scores improved significantly. The remediation exercises included additional classwork and homework assignments which focused solely on sketching and visualization, and students were required to sketch the solution to most CAD assignments and have the sketches checked by their instructor prior to beginning work on the computer. There were sketching and/or visualization components included on each test throughout the semester and also on the final comprehensive exam.

In the semesters following implementation of the remediation in the initial 2-D course, all students who enrolled in the 3D-focused second course in the series, both those who received remediation in the first course and those who had enrolled in a different section, were given the PSVT as a pre and posttest. The test scores of the students who had not received remediation in the first course were significantly lower at the beginning of the course than those who had received remediation, but there was some improvement at the end of the semester in their posttest scores. The posttest scores of the non-remediation group remained lower than those who had received remediation. However, the pre and posttest scores of the students who had received remediation in the 2D course remained unchanged by their instruction in the 3D course.

Student Demographics

Virginia State University is a historically black university (HBCU) with a student population that self-identifies as 98% black. The general characteristics of the subjects in this study include an average high school GPA of 2.62 and mean combined SAT score of 802 [2]. From 2002-2005 the mean nationwide combined score for all subjects taking the SAT was 1025 and the mean score for blacks nationwide was 858 [3]. The average age of the subjects in the study was 19 and they were typically first and second semester freshmen, along with some first semester sophomores, and eighty-seven percent of the subjects were male.

Math skills have been positively correlated with visualization ability and precollege preparation in mathematics and science is an important indicator of success for undergraduate majors in science and engineering. Entry requirements for students wishing to major in the Department of Engineering, Engineering Technology and Industrial Education and Technology at VSU include: a cumulative 2.2 GPA on a 4.0 scale; three units of mathematics including algebra I, and either geometry or algebra II; and two or three units of science, one of which must be a laboratory science [4]. These requirements were effective for entry in Fall 2005, previous admissions requirements were the same except for a minimum high school GPA of 2.0.

Differences in race/ethnicity exist in the proficiency levels in mathematics and science scores at the 4th, 8th, and 12th grade levels with white students having significantly higher scores at all levels [5]. Most students in this study were concurrently enrolled, or had been enrolled the previous semester, in an introduction to engineering and technology course where they are administered a freshman diagnostic math foundations test. This test covers; fractions, decimals, ratios/proportions and percents, integers, powers and exponents, coordinate geometry, measurement, geometry in plane, geometry in space, algebra and expressions, algebra and equations, radicals, word problems, and graph problems. The mean pretest score for freshmen was 59.7 percent and posttest mean was 76.6 percent [6].

The overall national average college graduation rate for black students is 38 percent, compared to 60 percent for white students and the graduation rate at historically black colleges and universities (HBCUs) is even lower than that with more than two thirds of entering freshman not going on to earn degrees [7]. The four-year graduation rate for students at VSU is approximately 16.9% and the percentage of students who graduate in five years is 31.8%. The five-year total includes those students who graduated in four years or less [2].

Course Descriptions

The subjects in this study were enrolled in one of two courses, DRFT 161 or DRFT 261. DRFT 161 focuses on 2D mechanical drawing / drafting and incorporates both hand sketching and 2D CAD. Topics covered throughout the course include orthographic projection, section views, auxiliary views, and basic dimensioning. There is no prerequisite to DRFT 161, and it serves as the prerequisite to DRFT 261, a course which focuses on 3D modeling, including CSG and parametric modeling. Topics covered in DRFT 261 include Boolean operations, extrusions and revolutions, extraction of multiview drawings from 3D models, dimensioning, 3D assembly, and animation of assemblies. Most engineering and technology students at VSU are required to take DRFT 161, unless they have previous experience in mechanical drawing / drafting and receive consent from both their advisor and the DRFT 261 instructor to skip DRFT 161 as a prerequisite.

Purdue Spatial Visualization Test: Visualization of Rotations

The Purdue Spatial Visualization Test: Visualization of Rotations (PSVT) tends to have high construct validity in the area of spatial visualization ability and appears to measure spatial

orientation [8]. The PSVT consists of 30 items of varying difficulty and is a 20 minute timed test appropriate for individuals age 13 and older. The test consists of items of four types, one type requiring rotation of 90° about one axis, another requiring rotation of 180° about one axis, one requiring rotation of 90° about two axes, and the fourth requiring rotation of 90° about one axis and 180° about another axis [9]. An example is shown in Figure 1.

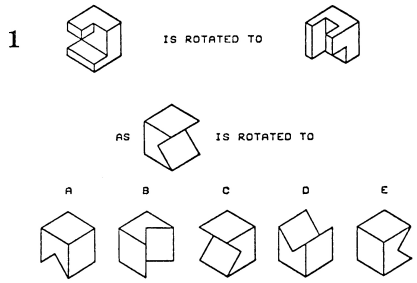

Figure 1. PSVT [9]

Remediation Activities

Because of an inadequate increase in scores on the PSVT posttest compared to the pretest for subjects taking DRFT 161 in the Fall semester of 2003 [1], beginning in the Fall semester of 2004, remediation exercises that supplemented ordinary course instruction were introduced into the course. Students were given five additional assignments, some of which were completed in class and some were assigned as homework, that focused solely on sketching and visualization. And for most CAD assignments, the solution had to be sketched on grid paper and the sketches were checked by their instructor before the students could begin work with the computer.

The sketching homework and classwork exercises included missing view and missing line problems, multiview sketches from isometric drawings, and section and auxiliary view exercises. Each assignment had at least six and up to 20 sketches to complete. There was also a sketching and/or visualization component included in each test throughout the semester and on the final comprehensive exam. In the initial offering of the course in Fall 2003, the percent value placed on sketching and visualization on written tests was approximately 25 percent of the test grade and the subsequent remediation focused courses had an average of 40 percent of the test points in sketching. Students were informed before each test was administered of the approximate weight of the sketching problems on their upcoming test in order to help them better prepare. Figure 2 shows examples of the missing view and missing line questions typical of homework and tests.

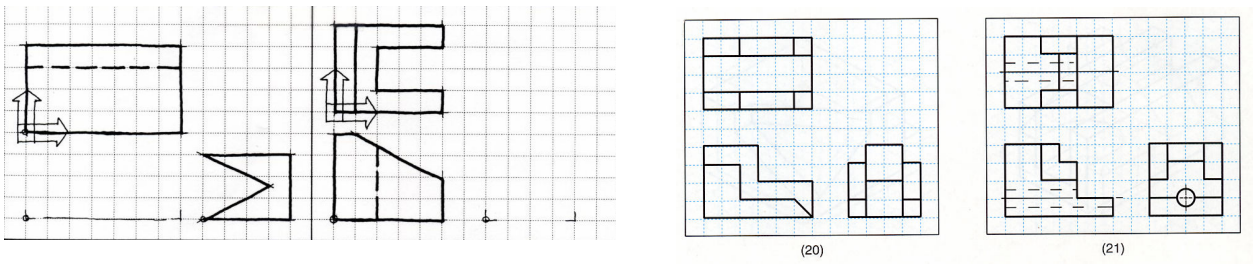

Figure 2. Missing view (left) [10] and missing line exercises (right) [11]

Pretest Scores

The PSVT was administered to all students attending class during the first week of the semester for DRFT 161 courses in the Fall semesters of 2003, 2004, and 2005. The mean pretest scores for each semester were; 13.6 in 2003, 15.7 in 2004, and 15.8 in 2005 with a grand mean of 14.6 for 55 subjects. As a basis of comparison to subjects in this study, mean pretest scores of engineering and technology students in other studies at other universities was approximately 23 to 24 out of 30 [12,13].

Students in DRFT 261 were also administered the PSVT during the first week of the semester during the Fall and Spring semesters of 2003 through 2005. The mean pretest scores for each semester were; 13.5 in Fall 2003, 17.8 in Spring 2004, 15.8 in Fall 2004, 17.2 in Spring 2005, and 13.1 in Fall 2005, with a grand mean of 16.4 for 46 subjects.

The scores for all students in DRFT 261 were also analyzed according to whether the students had taken as a prerequisite a section of DRFT 161 which contained remediation exercises intended specifically to enhance students' visualization abilities. The pretest scores of those who had received remediation in DRFT 161 had a mean of 22.2 while the mean score of those students who had either not taken the prerequisite at all, or not taken the course with remediation, was 15.0.

Posttest Scores

The PSVT was administered as a posttest to all students remaining in both DRFT 161 and 261 during the 14th or 15th week of the semester. The mean posttest score for DRFT 161 for the Fall semester of 2003 was 17.6. This section of the course did not receive additional remediation exercises. The mean posttest score for Fall 2004, the first course to receive remediation, was 23.3. Posttest mean for Fall 2005 was 21.6. The grand mean posttest score for all students in DRFT 161 is 19.6.

Posttest scores for students enrolled in DRFT 261 were; 17.7 in Fall 2003, 20.0 in Spring 2004, 18.1 in Fall 2004, 20.5 in Spring 2005 and 19.9 in Fall 2005. The mean posttest score in the Spring and Fall 2005 semesters for those students in 261 who had received remediation the previous semester in DRFT 161 was 23.6 and 25.0 respectively, while the mean of those who had not received remediation was 17.8 and 19.0. The grand mean posttest score for all subjects who have taken DRFT 261 is 19.8.

Discussion

The students in the sections of DRFT 161 receiving remediation had an increase in their PSVT scores from a pretest mean of 15.7 to a posttest mean of 22.4, which was a higher increase than achieved by the students in the course not receiving remediation. The non-remediation course only had an increase in scores from a pretest score of 13.6 to a posttest score of 17.6 (Figure 3).

	Pretest Mean	Posttest Mean
All DRFT 161 Scores	14.6	19.6
DRFT 161 N*	13.6	17.6
DRFT 161 R**	15.7	22.4

* Subjects who did not receive remediation
** Subjects enrolled in course with remediation

Figure 3. DRFT 161 pre and posttest PSVT scores

The sample size of 27 pretest scores and 15 posttest scores from those students who have taken the remediation section is small and therefore would only show if there are any moderate to large differences between these students' pre and posttest scores. At least 30 responses are required in a statistical sample to get an approximately normal distribution, one that approximates the symmetrical bell-shape of the normal curve [14]. Student's t-test may be used to find the significance of the difference between samples if the sample size is less than 30 [15]. Both the pre and posttest scores were approximately normally distributed (Figure 4) with the pretest scores being slightly negatively skewed at -.159 and the posttest scores also slightly negatively skewed at -.298.

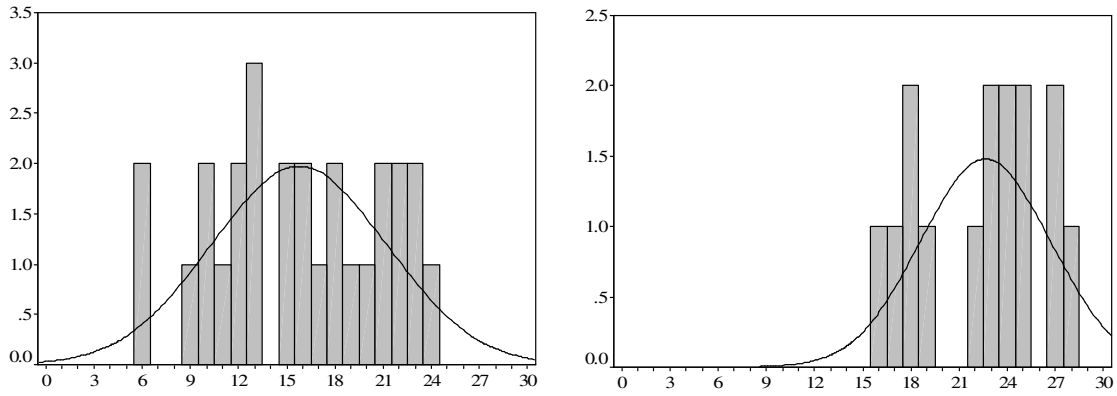

Figure 4. DRFT 161 pretest (left) and posttest (right) histograms

The t-test results (Figure 5) when comparing pre and posttest scores for the DRFT 161 remediation group were significant at α=.01 which shows that there was considerable improvement in their visualization abilities from the beginning to the end of the semester in which they received remediation. Also, when comparing only the posttest scores of subjects who received remediation to those who did not (Figure 6), the results were significant at α=.01 indicating that the remediation caused a significant increase in their visualization abilities as measured by the PSVT.

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
161 Remediation Pretest	15.508	26	.000	15.7407	13.6544	17.8271
161 Remediation Posttest	22.210	14	.000	22.4000	20.2369	24.5631

Figure 5. T-test of DRFT 161 remediation pre and posttest scores

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
161 Remediation Posttest	22.210	14	.000	22.4000	20.2369	24.5631
161 Non-remediation Posttest	17.981	23	.000	17.5833	15.5605	19.6062

Figure 6. T-test of DRFT 161 remediation and non-remediation posttest scores

The mean pretest score for students in DRFT 261 who had received remediation in DRFT 161, was 22.2 while the mean score for students who had not previously received remediation was 15.0 (Figure 7). The difference in these pretest scores measured with a t-test was significant at α=.01 which indicates that those students who had previously received remediation retained their abilities and those who had not received remediation had lower visualization abilities at the beginning of the course, similar to the beginning DRFT 161 students. There was also a significant difference in the posttest scores of the two different groups of students (Figure 8) with the non-remediation groups' scores remaining lower than the remediation group. The non-remediation groups' posttest scores in DRFT 261 did improve over their pretest scores as would be expected in a 3-D focused course; however, there was not as large a gain as there had been for the remediation sections of DRFT 161.

	Pretest Mean	Posttest Mean
All DRFT 261 Scores	16.4	19.8
DRFT 261 N*	15.0	18.6
DRFT 261 R**	22.2	22.5

* Subjects without remediation or without prerequisite
** Subjects receiving remediation in DRFT 161

Figure 7. DRFT 261 pre and posttest scores

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
261 Non-remediation Posttest	20.848	29	.000	18.6333	16.8054	20.4613
261 Remediation Posttest	16.218	12	.000	22.4615	19.4439	25.4791

Figure 8. T-test of DRFT 261 remediation and non-remediation posttest scores

These results seem to indicate that taking the remediation section of DRFT 161, the 2-D course, had a positive affect on students' visualization abilities. The students who received remediation tended to retain their abilities because their DRFT 261 pretest scores were not significantly different than their DRFT 161 posttest scores. The 3-D focused work the students did throughout the semester in DRFT 261 did not significantly further enhance their visualization abilities. In contrast, the DRFT 261 students who had not previously received remediation, although they did show some improvement throughout the semester, did not have posstest scores equivalent to the posttest scores of subjects receiving remediation in DRFT 161. The nature of the DRFT 261 does not allow for the intensive remediation that has been implemented in DRFT 161, therefore that may contribute to students' visualization abilities not improving in DRFT 261 as much as they did in the remediation section of DRFT 161.

Research has shown that the use of visualization in math and science related courses enhances both the visualization skills of students and the learning outcomes of the math and science related courses. Hands on experiences, field observations, use of graphing calculators, and science laboratory equipment increased opportunities for the students to create mental models which they could then relate to different academic areas and to daily life [16]. As was previously noted, the students in this study had lower than desired skills in basic math, including algebra and geometry. However, their diagnostic math test scores improved over the course of the semester [6] and whether the improvement can be attributed to the college algebra and trigonometry course most students were concurrently enrolled in, the intro to engineering and technology course that administered the diagnostic test, the mechanical drawing course DRFT 161, or a combination of all three has not been determined.

More data must be collected over the long term to determine the success of the remediation in DRFT 161 and its affect not only on that course, but on the subsequent course, DRFT 261, and on the students' overall success in their major. Since VSU is a small university, and class sizes in DRFT 161 and 261 are typically 10-20 with only one section every semester, or even every other semester depending on student need and availability of faculty, it will take some time to gather enough data to have great statistical significance.

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