AC 2011-1339: LONG-TERM IMPACT OF IMPROVING VISUALIZATION ABILITIES OF MINORITY ENGINEERING AND TECHNOLOGY STUDENTS

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Long-term Impact of Improving Visualization Abilities of Minority Engineering and Technology Students

Abstract

Retention in the major and graduation rates of minority students in STEM related fields tend to be lower than their non-minority peers, especially so at HBCUs. Previous studies found that students enrolled in introductory engineering graphics courses at Virginia State University, an HBCU, had 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. Because of the positive correlation between visualization ability and academic success in STEM courses, changes were made to the engineering graphics courses to add a variety of visualization enhancing activities including the use of sketching, blocks and multimedia. The result of these activities was improvement of the students' visualization abilities and it was hypothesized that this improvement would also positively affect the students' overall academic success.

To assess the long-term impact of visualization remediation on overall student success, data was collected on the students in the test group and also those in a control group who enrolled in sections of the engineering graphics courses that did not include visualization-specific instruction. Along with retention and graduation rates, statistics are compared for overall GPA and grades earned in math and physics courses. Analysis found significant differences in the students' GPAs with higher averages earned by those students in the test group. Also a higher percentage of students in the test group were retained both in an engineering or technology major and at the university even if they did change their major.

Introduction

As part of ongoing research, data was gathered on the visualization abilities of students enrolled in introductory engineering graphics courses at Virginia State University, an HBCU. The pretest scores of these students on the Purdue Spatial Visualization Test (PSVT) (Guay, 1976) were significantly lower than the average expected for incoming engineering and technology students. The visualization abilities of these subjects were improved through a variety of methods including sketching, haptic activities and multimedia exercises. The content of the courses varied slightly throughout the years referenced in this study but consistently covered the topics of orthographic projection, section views, auxiliary views, basic dimensioning and creation of technical drawings in both 2D and 3D CAD (Study, 2006, and Veurink, et al., 2009).

The overall national average college graduation rate for black students has improved over the last several years but at 43 percent it is still quite low when compared to 63 percent for white students. At HBCUs however, the graduation rate is even lower with an average of less than a third of all students who enrolled in an HBCU completing bachelor's degrees. Curricula oriented toward the sciences also tended to have lower graduation rates for blacks than those in the liberal arts. The high attrition rates are often attributed to inadequate K-12 preparation (Black student college, 2007). At Virginia State University, the mean freshmen cohort graduation rates have increased over time. The earliest data available was from 1992 when the cohort had a four year

graduation rate of 5 percent, a five year rate of 21.7 percent and a six year rate of 25.6 percent. The most recent data available is for the cohort that entered in 2003 with a six year rate graduation rate for all students across all majors of 39.3 percent. The average cohort graduation rates considering all students enrolled from 1992 to 2003 for students at Virginia State University are 18.8 percent in four years, 33.4 percent in five years, and 38.5 percent in six years (State council, 2010).

Since improving visualization abilities has been linked to increases in grade point averages and retention rates (Sorby, 2009) in other studies, longitudinal data was collected on the students enrolled in sections of engineering graphics courses that had specific instruction focusing on visualization. This data was compared to that of students who were enrolled in other sections of the courses where no additional visualization activities were included in the instruction. The primary focus of the coursework in the control group was CAD-specific tutorials, lectures, and written assignments. The test sections of the course were all taught by a single instructor and typically were the only sections of the course offered in a given semester so students enrolled in the test sections did not self-select. Class sizes range from 9 to 24 with typical class size of 20 students.

Student Demographics

Subjects in this study were primarily freshmen and sophomores majoring in engineering, engineering technology, or industrial technology with a mean age of 19.9 years. Of the students who received instruction specifically intended to improve their visualization abilities, complete follow up data was gathered on 40 male and 16 female subjects. Data was also gathered on a control group of 46 male and 5 female subjects who enrolled in sections of the engineering graphics courses that did not receive the visualization specific instruction. Of the 107 total subjects, 95 percent self identified as black. The median SAT scores for incoming freshmen during the time of this study were 410 for math, 420 for reading, and 410 for writing. The median high school GPA was 2.70 and 40 percent of incoming freshmen were in the bottom half of their graduating class. During the time of the study, the percent of students at Virginia State University who applied for financial aid and demonstrated financial need with a family income of less than $10,000 was 61 percent (State council, 2011).

Visualization Instruction

From the Spring 2004 semester through the Spring 2007 semester, students who enrolled in the test sections of the engineering graphics courses were given assignments that focused on sketching and visualization both in class and for homework. Students also were required to turn in sketches of solutions before beginning work on CAD drawings. The sketching exercises included missing view and missing line problems, multiview sketches from isometric drawings, and section and auxiliary view exercises. The individual assignments ranged from 6 to 20 sketches. Written tests and quizzes throughout the semester also contained sketching components as well as the final comprehensive exam. Sketching activities comprised approximately 40 percent of the overall grade in the courses (Study, 2006).

Starting in the Fall 2007 semester, as part of the EnViSIONS project (Veurink, et al, 2009), students enrolled in test sections of the engineering graphics courses completed modules using the Introduction to 3D Spatial Visualization: An Active Approach workbook and software by Sorby and Wysocki (2003). Topics covered in the workbook included: isometric sketching, orthographic projection, flat patterns, rotation of objects, object reflections and symmetry, cutting planes and cross sections, surfaces and solids of revolution, and combining solids. The workbook modules were primarily assigned as in-class work. Other class work consisted of instruction in CAD, dimensioning, drawing standards, and file management.

The effect of the visualization instruction, regardless of the method, showed improvement in the subjects' visualization abilities as measured by the PSVT. The grand mean pretest score for 156 subjects across multiple studies was 15.4 out of a possible 30 points which was significantly below the expected score for freshman engineering and technology students. The grand mean posttest score across the multiple studies was 19.88 which approached the expected mean and the improvement was statistically significant. In order to assess whether the instruction and subsequent improvement of visualization abilities had any long term effects, longitudinal data including grade point average and retention was collected on as many students as data was available.

Grade Point Averages

The mean overall GPA of 56 students in the test group was 2.67 compared to the control group mean of 1.89 for 51 students. It is recommended, but not required for all majors, that students maintain a 2.0 GPA in their major courses regardless of overall GPA. Virginia State University's undergraduate catalog requires that

> A new student (freshmen or transfer student without an Associate Degree) must earn a minimum grade point average of 1.5 each semester during the first two regular semesters in residence. Thereafter, the student must earn at least 2.0 semester average each regular semester (to avoid Academic Warning) or have a cumulative average of 2.0 (to avoid Probation or Suspension).
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> Transfer students with the Associate Degree must maintain a 2.0 semester average each regular semester (to avoid Academic Warning) or have a cumulative average of 2.0 (to avoid Probation or Suspension) to remain in good academic standing (Virginia State University, 2010).

The calculation of overall GPAs included the final GPA of graduating seniors, the final GPA of students who left the University, and the GPA of currently enrolled students ending the Fall semester of 2010. These GPAs were from two to five semesters after the subjects were enrolled in either a test or control section of the engineering graphics course.

The GPA in the subjects' math and physics courses was also collected. Math courses used to calculate the average ranged from introductory college algebra to calculus. At Virginia State University, students receive separate grades for physics lectures and labs and both lecture and lab grades were used in the calculations in this study. Students in the test group had an overall math

GPA of 2.45 and a physics GPA of 2.07. Control group subjects had a math GPA of 1.11 and a physics GPA of 1.02.

Retention Rates

Of the 56 students in the test group, 14 graduated, 40 are still retained in their major, 1 changed major, and 1 withdrew from the university. Of the 51 students in the control group, 4 graduated, 35 remain enrolled in their major, 2 changed major, and 10 withdrew from the university. Not all those students who left the university were suspended because of a low GPA.

Analysis

Using a t-test to compare the overall grade point averages of the test versus control group (Table 1) found the test group had a significantly higher GPA.

Table 1. Overall GPA

	Mean	SD	p
Test Group	2.67	0.589	0.00
Control Group	1.89	0.619	

The t-tests that compared the math and physics grade point averages were also significant as shown in Tables 2 and 3 with subjects in the test group having significantly higher GPAs.

Table 2. Math GPA

	Mean	SD	p
Test Group	2.45	0.858	0.00
Control Group	1.11	0.716	

Table 3. Physics GPA

	Mean	SD	p
Test Group	2.07	0.890	0.00
Control Group	1.02	0.823	

Retention and Graduation Rates

The students in the test group had a higher graduation rate when compared to those in the control group, 25 percent versus 8 percent. However, these rates can not be directly compared because the majority of the students in both groups enrolled in an engineering graphics course as

freshmen or sophomores and the data available on the test group covers six years and that available on the control group students is primarily from the past two years, thus not giving all of the subjects time to complete the coursework necessary to graduate. A better comparison is the retention in their major and at the university. Students in the control group had a higher rate of withdrawal from the university although 69 percent were still retained in their major (Table 4).

Table 4. Retention and Graduation Rates

	Graduated		Retained in Major		Changed Major		Withdrew	
	N	%	N	%	N	%	N	%
Test Group	14	0.25	40	0.71	1	0.02	1	0.02
Control Group	4	0.08	35	0.69	2	0.04	10	0.19

Discussion

The percentage of black students earning science and engineering degrees does not equal their representation in the US population. In 2006, blacks represented 12 percent of the US population and earned only 8.7 percent of all science and engineering degrees. Of the total number of students enrolled at HBCUs, 17 percent were studying science and engineering fields (National Science Foundation, 2009) but less than half of them earned degrees because the graduation rates at HBCUs are typically lower than non-minority serving institutions (Black student college, 2007). Lack of retention and low graduation rates of blacks and other minorities in STEM fields is often attributed to lack of pre-college preparation. The relatively low SAT scores and high school grade point averages of the subjects in this study reflect this lack of pre-college preparation. The below average pretest PSVT pretest scores are another indicator of inadequate preparation and since academic success in STEM fields is associated with abilities in spatial visualization, the low scores were of concern.

After implementing visualization specific instruction in introductory engineering graphics courses, students who had initially tested significantly below average in their visualization abilities had posttest PSVT scores that were approximately equal to the expected mean for freshman engineering and technology students. When this test group was compared to a control group of students who did not receive the visualization instruction in their introductory engineering graphics courses, the test group's subjects had significantly higher overall grade point averages and significantly higher GPAs in their math and physics courses. A higher percentage of students in the test group, 96 percent, graduated or were retained in their majors and than in the control group, where 23 percent of the subjects withdrew from the university or changed their majors.

Whether the visualization instruction used a workbook, blocks, and multimedia instruction (Veurink, et al, 2009) or sketching exercises such as missing view and missing line problems, multiview sketches from isometric drawings, and section and auxiliary view exercises (Study, 2006), and whether the CAD portion of the course focused more 2D or 3D, all instruction involved orthographic projection and some form of sketching and haptic interaction with physical objects. The skills gained from these activities help students create mental models that

can aid in interaction with abstract concepts across the curricula, especially in their math and science studies. This is reflected in part in the higher GPAs in the math and physics courses of the subjects in the test group.

Although the differences in grade point averages and retention are statistically significant, this study does have limitations. Potential problems include lack of complete data on all subjects who received visualization remediation and not controlling for outside factors such as advisement inconsistencies, financial aid status, work schedule, and if the student was the first person in their family to attend university.

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