Engineering Design Graphics Journal (EDGJ)
Spring 2011, Vol. 75, No. 2
http://www.edgj.org

ISSN: 1949-9167

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The 2010-2011 Oppenheimer Award recipient is Nancy E. Study of Virginia State University for her paper *Long-term Impact of Improving Visualization Abilities of Minority Engineering and Technology Students: Preliminary Results*. Dr. Study's paper appears on the following pages.

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

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Abstract

Previous studies found that students enrolled in introductory engineering graphics courses at a historically black university (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. Since the ability to visualize is linked with success in engineering and technology studies, changes to the courses were made that resulted in improvement of these students' visualization abilities. Activities included the use of sketching, blocks and multimedia. It was hypothesized that improving the students' visualization abilities would also improve their overall academic success. Retention in the major and graduation rates of minorities in STEM related fields tend to be lower than their non-minority peers, especially so at HBCUs. To assess the long-term impact of visualization remediation on student success in engineering and technology majors, data was collected on students in a test group and also those in a control group who enrolled in other sections of the engineering graphics courses. Statistics were compared for overall GPA and grades in math and physics courses. Other data gathered included whether the students were retained in the major and at the university. Significant differences were found 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

Beginning in 2003, data was gathered on the visualization abilities of students enrolled in introductory engineering graphics courses at Virginia State University (VSU), an HBCU. These subjects had significantly lower than average scores on the Purdue Spatial Visualization Test (PSVT) (Guay, 1976) when it was administered during the first week of the semester. 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 VSU,

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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%, a five year rate of 21.7% and a six year rate of 25.6%. The most recent data available is for the cohort that entered in 2003, and the average graduation rates over time for students at VSU are 18.8% in four years, 33.4% in five years, and 38.5% in six years (State council, 2010).

Since improving visualization abilities has been linked to better grades and retention, (Sorby, 2009) in other studies, longitudinal data is in the process of being collected on the students who enrolled in sections of engineering graphics courses that had specific instruction focusing on visualization. This data is being compared to that of students who were enrolled in other sections of the courses taught by different instructors where no additional visualization activities were included in the instruction.

Visualization Instruction

From Spring 2004 through Spring of 2007, students 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 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% of the overall grade in the courses (Study, 2006).

Beginning in Fall 2007, as part of the EnViSIONS project (Veurink, et al, 2009), students enrolled in test sections of the engineering graphics courses completed modules of the textbook 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.

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Subjects' Longitudinal Data

Of the students who received instruction specifically intended to improve their visualization abilities, complete follow up data is currently available on 21 male and 9 female subjects in the test group. Data was also gathered on a control group of 30 male and 3 female subjects who enrolled in sections of the engineering graphics courses that did not receive the visualization specific instruction. Of the 63 total subjects, 98% self identified as black.

Grade Point Average

The mean overall GPA of the students in the test group was 2.69 compared to the control group mean of 1.91. It is recommended, but not required for all majors, that students maintain a 2.0 GPA in their major courses regardless of overall GPA. VSU'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).
>
> 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 Spring 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 VSU, 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 2.49 and a physics GPA of 1.97. Control group subjects had a math GPA of 1.13 and a physics GPA of 0.80.

Retention Rates

Of the 30 students in the test group, 12 graduated, 16 are still retained in their major, 1 changed major, and 1 withdrew from the university. Of the 33 students in the control group, 2 graduated, 20 remain enrolled in their major, 1 changed major, and 10

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withdrew from the university. Not all those students who left the university were suspended because of a low GPA.

Analysis

Grade Point Averages

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	2.69	0.594	0.00
Control Group	1.91	0.621	

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	2.49	0.961	0.00
Control Group	1.13	0.743	

Table 3. Physics GPA

	Mean	SD	p
Test Group	1.97	0.841	0.00
Control Group	0.80	0.922	

Retention and Graduation Rates

The students in the test group had a higher graduation rate when compared to those in the control group, 40 percent versus 6 percent. Students in the control group had a

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higher rate of withdrawal from the university although 61 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	12	0.40	16	0.53	1	0.03	1	0.03
Control Group	2	0.06	20	0.61	1	0.03	10	0.30

Discussion

In 2006, blacks earned 8.7% of all science and engineering degrees while they represented 12% of the US population. Of the total students enrolled at HBCUs, 17% were studying science and engineering fields (National Science Foundation, 2009). However, the graduation rates at HBCUs were typically even lower than non-minority serving institutions (Black student college, 2007). Reasons for the lack of success in STEM fields vary but are often attributed to lack of pre-college preparation. Since academic success in STEM fields is associated with abilities in spatial visualization, the low pretest PSVT scores of the subjects in this study were of concern.

After implementing visualization specific instruction in introductory engineering graphics courses, students who were below average in their visualization abilities had posttest PSVT scores that were approximately equal to the expected mean. When this test group was compared to students who did not receive the visualization instruction, the control group, the test group's subjects had significantly higher overall grade point averages and significantly higher GPAs in their math and physics courses. A direct comparison of graduation rates is not appropriate because the students in the control group are primarily sophomores and juniors. However, the control group did have a larger rate of withdrawal from the university, 30% compared to 3% of the test group.

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 learned 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 may be indicated by the higher GPAs and graduation rates of the subjects in the test group.

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Longitudinal data is still being collected on subjects who have received visualization instruction and it will be compared to students in the control group. Additional analyses will be conducted comparing the long-term success of the students in the two groups including retention based on how long after completing either a test or control section of the engineering graphics course the students remain enrolled and/or graduate.

Due to the small sample size and not controlling for a variety of external factors including inconsistencies in academic advisement, financial aid status, whether or not the student was working and if so, how many hours a week, firm conclusions cannot be drawn from the results. However, the initial data does suggest that the visualization instruction be continued because of the potential positive long-term effects.

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About the Author

Nancy E. Study is an associate professor in the Department of Engineering and Technology at Virginia State University, where she has taught since 2002. She is an active member of the Engineering Design Graphics Division of ASEE and has served as the Associate Editor of the Engineering Design Graphics Journal since 2006. Study has served as a reviewer of conference abstracts and papers for the Engineering Design Graphics Division's Annual and Mid-Year conferences, along with serving on multiple NSF review panels. Her research interests include haptics and visualization.
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