EnViSIONS at Virginia Tech

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ABSTRACT – As part of the EnViSIONS (Enhancing Visualization Skills--Improving Options aNd Success) project, a one credit hour stand-alone elective course in spatial visualization is being offered at Virginia Tech. The course is targeted to first-semester engineering students and engineering-bound students who perform poorly on a visualization screening test. In the first offering of the course, in fall 2007, a series of pre- and post-test assessments showed gains of 16-28%, and students generally felt that the materials used were appropriate. The course is slated to be offered each fall. Future plans include a longitudinal study of retention and success for students who elect to take the course and a matching cohort of students who do not take the course.

I. University Demographic

Virginia Tech is a large land grant public university located in southwest Virginia. The university offers undergraduate and graduate degrees in eight colleges. Total undergraduate enrollment is 23,000 (VT Factbook, 2008). Virginia Tech is a residential campus with almost all freshman students living on campus, and most upper-class students living within a five-mile radius. Approximately 25-30% of the undergraduate population is non-white.

The College of Engineering at Virginia Tech is home to thirteen departments: Aerospace and Ocean Engineering, Biological Systems Engineering, Chemical Engineering, Civil and Environmental Engineering, Computer Science, Construction and Engineering Management, Electrical and Computer Engineering, Engineering Education, Engineering Science and Mechanics, Industrial and Systems Engineering, Materials Science and Engineering, Mechanical Engineering, and Mining and Minerals Engineering. Total undergraduate enrollment in the College of Engineering is approximately 5,800 (VT Factbook, 2008). All undergraduate students at Virginia Tech are required to own a laptop computer, but students in the College of Engineering are required to own a tablet PC convertible laptop.

Freshmen entering the College of Engineering are enrolled as General Engineering (GE) students. Once these students complete a prescribed sequence of courses (including math, chemistry, physics, freshman English, and two freshman engineering courses), they are able to transfer to their major department. The freshman engineering courses are offered through the Department of Engineering Education and focus on the engineering profession, ethics, problem solving, computer programming, graphics communication, and design.
II. Spatial Visualization Curriculum

At Virginia Tech, the spatial visualization curriculum closely follows the content developed at Michigan Tech, which we have implemented through a stand-alone, one-credit elective course in Engineering Education. This optional course targets first-year engineering students and also engineering-bound students who enter the university as University Studies students. The course is offered once a year in the fall semester and was first offered in fall 2007.

The class meets once a week for 75 minutes throughout the 15-week semester. The general approach each week is the same. First, time is spent reviewing homework and answering questions related to the module covered in the previous week. Then material for the current module is introduced using a brief PowerPoint presentation with in-class exercises. Following that, students work through the visualization software for the module before leaving class. Students are expected to bring their own laptops/tablets to class each week, and they generally work through the visualization software independently or with minimal consultation with a neighbor. Homework is assigned from the workbook or, in the case of the inclined planes and single curved surfaces module, as a separate handout. Several exercises on the Penn State Eire VIZ website (Visual Assessment and Training, http://viz.bd.psu.edu/viz/) are also assigned as out-of-class work, and these selections are linked to specific modules.

All nine modules in the textbook Introduction to 3D Spatial Visualization: an active approach (Sorby, 2003) are covered in order, with the supplemental materials on inclined and curved surfaces inserted between orthographic drawings (Module 2) and folding of flat patterns (Module 3). The paper folding exercises on the VIZ website are assigned with the flat patterns module of the text, the “Rotating Blocks” exercise is used with the text module on rotation of objects about a single axis, and the VIZ “Mental Rotations” exercises are used to supplement the text’s Rotation of Objects about Two or More Axes module.

The visualization course is graded on an A-F basis, with fifty percent of the course grade based on class participation and homework. There are two hourly tests, each of which accounts for 15% of the semester grade, and a final exam that accounts for 20%. The first test covers materials from Modules 1 and 2 (isometric sketching and orthographic projections) and the supplemental materials on inclined and curved surfaces. The second test covers Modules 3, 4, and 5 (Flat Patterns, Rotations of Objects about a Single Axis, and Rotation of Objects about Two or more Axes). The final exam covers Modules 6, 7, 8, and 9 (Object Reflections and Symmetry, Cutting Planes and Cross Sections, Surfaces and Solids of Revolution, and Combining Solids) and the post-test evaluations discussed later.

Throughout the semester, the students have access to several manipulatives that help impart visualization skills. During the first lecture, students are given a set of fifteen snap blocks to use for the semester. With these blocks, students create models of the objects they are asked to sketch. During the modules focusing on rotation, students are also provided with a paper handout to help them identify the proper axes and directions for requested object rotations. The handout, consists of an x-z coordinate rose with the positive x- and z-axis labeled. An image of the rotation aid handout is provided in Figure 1. Students can place a snap-block model of an object in the first quadrant of the handout and then use the right hand rule to determine how to rotate the object. Both positive and negative rotations of any amount about the y-axis keep the base of the snap-cube object in the plane of the
paper handout. Limited (90°) negative rotation about the x-axis or positive rotation about the z-axis are also
easily accomplished/visualized without lifting the snap-cube object. During the module on cutting planes and
cross-sections (Module 7), swimming pool “noodles”
that have been cut to various lengths and then sectioned
along bisecting cutting planes are used in class as an
aid to help students see how an object’s features may
appear elongated, shortened, or unaltered on the section
created by the cutting plane.

III. Students Enrolled in the Curriculum
The Introduction to Spatial Visualization course at
Virginia Tech is targeted for first-year engineering and
engineering-bound students. For the Fall 2007
semester, a diagnostic screening test used to identify
students who could benefit from taking the course was
assembled and offered to target students in two settings.

The first setting was an evening session held for pre-
enrolled freshmen who were participating in a summer
bridge program sponsored by the Center for the
Enhancement of Engineering Diversity (CEED). All
students in the bridge program completed the
diagnostic as an exercise. An additional screening was
held during the first week of the fall 2007 semester; it
was advertised to all students enrolled in the first
semester general engineering course and to all
University Studies students who had identified
themselves as engineering-bound. The Virginia Tech
diagnostic test used in fall 2007 included several items
on rotation and items requiring recognition of objects
from different views (horizontal, front, or profile).
Students who performed poorly on the diagnostic
screening test were encouraged to take the optional
course.

A total of 16 students enrolled in Introduction to
Spatial Visualization in fall 2007, with fifteen students
completing the term. Of these students, eleven agreed
to allow us to access their academic records and to
follow their academic progress while at Virginia Tech.
Four of the eleven students were female, half
engineering majors and half University Studies majors.
Of the seven male students, three were engineering
majors and four were University Studies majors. All
but two of the students were freshmen. In terms of
self-reported ethnicity, two of the students were white,
five African American, one Hispanic, two Asian, and
one unspecified. All students were concurrently
enrolled in Calculus I or a higher level math course.

IV. Assessment
A set of pre- and post-tests were given to all
students enrolled in the visualization course at the
beginning and end of the semester, respectively. The
pre- and post tests consisted of the 30-question Purdue
Spatial Visualization Test – Rotations (PSVT-R), the 10 question Lappan test, and a modified 10-question Mental Cutting Test (MCT). The average pre-test scores on the three tests at the beginning of the semester was 49-58%. At the end of the semester, average scores ranged from 74-79%. Average scores for the three pre- and post-tests are provided in Table 1.

Table 1: Fall 2007 average scores on pre- and post-tests.

<table>
<thead>
<tr>
<th>Test</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Average increase in number of questions answered correctly</th>
<th>Range of increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSVT-R (30 Questions)</td>
<td>17.8</td>
<td>22.7</td>
<td>4.9</td>
<td>+13 to -1</td>
</tr>
<tr>
<td>Lappan (10 Questions)</td>
<td>4.9</td>
<td>7.9</td>
<td>2.8</td>
<td>+5 to -1</td>
</tr>
<tr>
<td>MCT (10 Questions)</td>
<td>4.9</td>
<td>7.4</td>
<td>2.5</td>
<td>+6 to 0</td>
</tr>
</tbody>
</table>

Based on average scores, the greatest observed increase was in the Lappan test (28%), the content of which corresponded most closely to course content in Modules 1 and 2 (Isometric Drawings and Coded Plans and Orthographic Drawings, respectively). In general, we observed that students who scored less than 50% on a pre-test saw a larger gain on the corresponding post-test (see Table 2).

In fall 2007, students evaluated each instructional module at the completion of the module. Students typically rated the quality of the module as good to very good. Each of Modules 1, 2, 4, 7, and 9 (Isometric Drawings and Coded Plans, Orthographic Drawings, Rotations about a Single Axis, Cutting Planes and Cross Sections, and Combining Solids, respectively) did have one student rate the module only Fair. For each module, at least 75% of the students felt the length was appropriate and at least 71% felt the level was appropriate for their needs. At least two students felt the level was too simple for their needs for each of Modules 1, 2, and 6, (Isometric Drawing and Coded Plans, Orthographic Drawings, and Object Reflections and Symmetry, respectively), while the supplemental inclined and curved surfaces module and Module 7 (Cutting Planes and Cross Sections) each had two students indicate that the level was too advanced.

Course grades for Introduction to Visualization were high because 50% of the course grade was based on attendance and effort. The average course grade for the semester was 3.8/4.0, with one student earning a C+, one student an A-, and the rest each earning an A. Again, we note that the post-test evaluations were included in the students’ final exam scores, and they composed 50% of that exam.

V. Recommendations and Future Directions

The Introduction to Spatial Visualization Course is being offered again in fall 2008, and it is currently in the university governance process of being approved as a permanent course to be offered each fall. In fall 2008, all students enrolled in the general first semester
engineering course completed the 30-question PSVT-R exercise as a diagnostic screening during the first week of classes. This is more in line with Michigan Tech screening procedures (through use of the same instrument and in covering almost all of the freshman engineering class), but the timing of the Virginia Tech screening is later and falls after most students have already established their fall class schedule. Approximately 13% of the 1381 engineering students who completed the PSVT-R screening scored less than 60%. This observation is in agreement with Michigan Tech numbers for fall 2008 (about 120 failing of about 900 tested). During the first week of classes, the PSVT-R was also administered to a group of 35 Virginia Tech University Studies freshmen who intend to major in engineering, and seventeen percent (17%) of those students scored less than 60%. Students who scored less than 60% on the PSVT-R, and who indicated that they were willing to be contacted as a result of their score, were invited to enroll in the spatial visualization course. Eighteen students are now enrolled for fall 2008. As a result of having initial PSVT-R scores for almost all of the first-year engineering students, we plan to identify a control cohort by matching initial PSVT-R scores, gender, Math SAT scores, ethnicity, and academic level. The matching control cohort will be used in a comparison of retention and academic success between students who self select to take the elective spatial visualization course and those who do not. By building such a matching cohort, we hope to attain some level of matching on prior knowledge and on base potential to succeed between students in the control and in the experimental cohorts. But, we cannot hope to match motivations through building a matching control cohort, and motivation is a key component in a student’s decision to take action to improve their odds of success, that is, to self select to enroll in the visualization course.

VI. References

