Assessment of a Visualization-Based Placement Exam
for a Freshman Graphics Course

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ABSTRACT

At Michigan Technological University (MTU) many freshman engineering students enroll who have already taken one year or more of high school drafting or technical drawing. For many of these students, freshman graphics courses are redundant and these students are frustrated that they must spend time re-learning material they have already mastered. A placement test was designed to assess a student's visualization skills as well as their understanding of conventional practices. As a part of a re-structuring of the freshman graphics courses in the General Engineering department at MTU, the visualization-based placement exam was developed for those students who have a minimum of one year or prior graphics experience. This test was administered for the first time in the Fall of 1997 and preliminary findings were reported during the 1997 mid-year Engineering Design Graphics conference in Madison, Wisconsin. This paper is a follow-up to that previous presentation and includes assessment results investigating how the student performance on the placement exam corresponds to their preparation and describes experiences from the use of this placement exam.

BACKGROUND

Incoming students in Mechanical, Civil and General Engineering typically enroll in one of two introductory graphics courses independent of their graphics preparation. These courses cover the majority of traditional engineering graphics topics and introductory descriptive geometry. The topics are taught using a mixture of sketching and instrument drawing techniques. Approximately 25% of incoming students in these engineering majors have no preparation in graphical communication while the balance have had some previous experience in art and/or drafting classes at the secondary or post-secondary level.

We have observed over several years that students with two or more years of prior drafting experience view the introductory graphics courses as remedial and boring. The academic performance level of these students is often below those who are learning graphics for the first time. Also, the educational value added by the introductory course is typically much larger for the novice when compared with students who have mastered the fundamental graphics techniques. Historical grade distributions in these courses are either typically skewed toward the upper end of the grading scale or show a bimodal shape. We assume that placing students into a graphics course consistent with their background and preparation will enhance both student and teacher performance. The students will be more motivated if they feel that they are learning something new. Enabling the instructors to focus on the novice student population will improve teaching effectiveness. We searched for an existing placement exam to assess visualization skills and engineering graphics knowledge without success. This prompted us to design and implement an exam that was suitable to screen incoming students in these areas.
Prior to writing the graphics placement exam we identified the visualization skills and graphic communication knowledge necessary in the engineering profession. This includes spatial visualization skills such as object rotation, 2-D to 3-D translation, 3-D to 2-D translation and mentally cutting through objects. These areas were assessed using a combination of standardized test problems and traditional engineering graphics problems. Some problems from the Purdue Spatial Visualization Test: Rotations (PSVT:R) developed by Guay\(^1\) were used to test mental rotation ability. Traditional engineering graphics problems such as missing view orthographic and section view problems were also used to assess other areas of visualization. Also identified for inclusion in the placement exam were several areas of engineering graphics standards. Problems used in MTU graphics courses were used to assess understanding of standard orthographic practices and conventions, standard dimensioning practices and scale reading ability. We also assessed the student's ability to read and interpret engineering drawings. Further detail of the questions accompanied by sample problems can be found in our previous paper.\(^2\)

The development of this placement exam resulted in fifty multiple-choice format questions testing both visualization ability and graphical communication knowledge. The test is subdivided into nine distinct areas—five which test various visualization abilities and four which test student understanding of standard graphical practices and conventions. Specifically the nine areas are: 1) Sample problems from the PSVT:R, 2) Orthographics (select the missing view), 3) Isometrics (select the appropriate isometric, given two views of an object), 4) Surface Identification, 5) Sections (given two views and a cutting plane line, select the resulting sectional view), 6) Scale reading, 7) View Selection and Conventions, 8) Dimensioning technique, and 9) Reading working drawings. Initial results show that the exam is effective at evaluating the overall graphic communication abilities of incoming students, and is also capable of identifying specific areas of strength and weakness.

The placement test was written and administered to a pilot group of twelve students during spring quarter in 1997. The pilot results showed a clear break at 75% correct, and allowed us to identify logistical problems with the test procedure. The first group of incoming students took the exam during freshman orientation at the start of the 1997-98 academic year. Only those new students with at least one year of previous drafting experience were permitted to take the placement exam. Our initial intent was to permit students achieving a score of 70% correct or greater on the exam to receive credit for their introductory engineering graphics course requirement.

**TEST RESULTS**

A total of 66 entering freshman in Civil and Environmental Engineering were eligible to take the placement exam during orientation and 53% of them passed the exam. We initially set the minimum passing score at 70%, however, after analysis of student responses to the various questions, we determined that there were 2-3 questions that had nearly a 0% correct response rate. Our conclusion was that these questions might have been too "tricky" and we modified our minimum passing score to 68%.

Student performance on the placement exam was further analyzed by investigating their
performance on each of the nine subject areas of the exam. Five of the subject areas primarily dealt with their ability to visualize in three dimensions and the four remaining areas dealt with their understanding of drawing standards and conventions. Since each area consisted of 5 questions (except for the reading drawings portion of the exam which contained 10 questions), a score of 3 or higher (60%) was considered passing and a score of 2 or lower (40%) was considered failing for that particular area. The students were also divided into four groups. Those who scored 78 or higher were designated as clearly passing the exam, and those who scored between 68 and 77 were considered to have "marginally" passed the exam. Likewise, those students who scored between 58 and 67 were designated as "marginally" failing the exam, and those who scored below 58 definitely failed the exam. Individual exams were analyzed and the results are presented in Table 1.

Table 1: Number of Students who Failed Specific Areas of the Exam

<table>
<thead>
<tr>
<th>Population Group</th>
<th>Sample Size</th>
<th>Number of Areas Failed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Passing (78% or higher)</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Marginal Passing (68%-77%)</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Marginal Failing (58%-67%)</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Failing (below 58%)</td>
<td>17</td>
<td>0</td>
</tr>
</tbody>
</table>

Average scores for each area of the exam were determined for the four groups of students. The results are presented in Figure 1a&b. The visualization content of the exam provided some interesting results. The average score for all four groups of students on the PSVT:R questions was very high, with little distinction between those who passed and those who failed. This is consistent with previous findings at MTU that students with previous drafting experience typically do well on this exam. For the remaining four areas of the exam dealing with visualization abilities, there is a clear delineation between those who passed the exam and those who failed the exam. An exception to this is in the series of the problems covering isometrics view interpretation. For this part of the exam, there was virtually no difference between the two marginal groups of students, however, there was a large distinction between those who passed and those who failed the exam.
For the graphical standards portion of the exam (the results are presented in Figure 1b), the average scores for all groups of students on the conventions and the scale reading areas were significantly lower than for other areas of the exam. In fact, for the scale reading area on the exam, none of the average scores was above passing (60%). For each area in this portion of the exam, there was little difference between the performance of the two groups of marginal students. There was a significant difference between those who passed and those who failed the exam. The majority of the students demonstrated sound print reading ability. We found this to be very interesting in light of the relative differences between them on the visualization portion of the exam.

High school transcripts of the students who attempted the placement exam were studied. Many of the students received more than the required one year of drafting or graphics instruction. There appeared to be a direct correlation between the amount of time spent in high school drafting courses and their performance on the placement exam. Only 4 of the 36 students who passed the exam did so with the minimum of one year drafting experience as required in our placement criteria. In fact, most of these students had 2-3 years of prior experience. In contrast, 17 of the 31 students who failed the exam had only one year of previous experience. Table 2 shows the average number of years in high school drafting courses for those students attempting the placement exam. As it can be seen from this table, in general, approximately 2.5 years of high school drafting experience on average are required in order to receive placement credit for GN131.
Table 2: Previous Drafting Experience for Students Taking the Exam

<table>
<thead>
<tr>
<th>Population Group (n)</th>
<th>Average Number of Years in High School Drafting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passed Exam (14)</td>
<td>2.54</td>
</tr>
<tr>
<td>Marginal Pass (21)</td>
<td>2.36</td>
</tr>
<tr>
<td>Marginal Fail (14)</td>
<td>1.82</td>
</tr>
<tr>
<td>Failed Exam (17)</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Phone interviews were conducted with several of the students who took the placement exam during the initial offering. Some common themes in the interviews with those who failed the exam emerged. Many of the students spent a great deal of time in their first year of high school drafting learning technique. Geometric constructions, use of the instruments, and use of computer software (mostly AutoCAD) were common components of their high school drafting courses. Many students said that they were making drawings always from either an actual object or from an isometric of an object. When sections were covered, only a small amount of time was devoted to the topic and the focus was again on technique and on the proper application of cross-hatching to a drawing. Those students with more than one year of drafting who failed the exam indicated that their subsequent years were mostly more of the same with different applications, i.e., architectural, mechanical, etc. Many of the students reported that they spent a great deal of time on computer drafting, mostly with AutoCAD. We suspect that these classes were more focused on "button-pushing" rather than on graphics fundamentals.

Some of the students who failed the exam went on to take the GN131 course in subsequent terms. When asked how GN131 compared to their high school drafting courses, students stated that the course was significantly different from what they had previously experienced. In fact, one student stated that he now understood why features must line up orthographically on a drawing. Several of the students who failed the exam stated that they did not feel confident when taking the exam--they felt that they did not have the background necessary to pass the exam.

Students who passed the exam reported a similar type of training/education in their first year of high school drafting. However, fewer of the people who passed the exam spent any time on the computer. In fact one student who passed the exam said that he didn't spend any time on the computer in high school and spent at least one semester doing nothing other than free-hand sketching. Most of the students said that they felt confident taking the test and thought that it was not a difficult test to pass.

Comparison with Students Enrolled in GN131
The placement exam was used as the final exam in GN131 for the fall term. A total of 41
students were enrolled in two sections of the course. The course stressed visualization and reading drawings and was completely sketching based. The average score on the exam for the students in the course was 79.6% compared to an average of 75.9% for those students who took the test as a placement exam and passed it. In fact, only 4 of the 41 students failed the final exam by our placement criteria (less than 68%) and only two people scored less than 60% on the exam. Of the students who failed the placement exam initially, four went on to take the GN131 course during the following fall quarter. Three of these four passed the exam as a final, and the fourth improved his score from 30% to 56%.

Student performance on the exam was analyzed and compared to the results obtained from the placement exam. In this analysis, we considered only those students who passed the placement exam (68% or higher) and those students who passed the GN131 course. In other words, we considered those students who received credit for the course on their transcripts. Table 3 shows a breakdown of the number of areas failed for these two groups of students. As it can be seen from the data presented in the table, the students in the course did slightly better than those who passed the placement exam at the beginning of the fall term. Nearly one-half of the GN131 students failed no areas of the exam, compared to only one-third of those who passed the exam during the placement procedure. In addition, 4 of the 5 students who took the course and failed three or more areas of the exam also failed the exam outright by our placement criteria.

### Table 3: Number of Students who Failed Specific Areas of the Exam

<table>
<thead>
<tr>
<th>Population Group</th>
<th>Sample Size</th>
<th>Number of Areas Failed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passed Placement Exam</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Participated Course</td>
<td>41</td>
<td>19</td>
</tr>
</tbody>
</table>

The average score on each part of the exam was computed for both groups of students and the results are presented in Figure 2a&b. As it can be seen from these figures, the average scores for both groups of students are fairly comparable. In some categories (scales, conventions, and orthographics), the students enrolled in the course seemed to perform significantly better than those who took the placement exam. Also interesting to note is that the average scores for those enrolled in the course were above 60% for each area, whereas for the students who passed the placement exam, the average on the scales area of the exam was only 51.6%.
Student feedback from the placement procedure has been generally positive. Students who have had several years of drafting/graphics experience in high school were grateful to have the opportunity to receive credit for their previous course work. From an instructor's point of view, this has proven to be a worthwhile endeavor. In the past, the graphics courses were populated by three groups of students: 1) students with several years of high school drafting experience, 2) students who may have some background but are not proficient in graphical communication, and 3) those students who are completely lost and who have poorly developed spatial visualization skills. By allowing the students in the first group to test out of the class, instruction can now be focused on the latter two groups--those students who need it the most. This has proven to be very beneficial from an instructional point of view. No one in the class is completely bored and unchallenged.

CONCLUSIONS

We have now administered the placement exam to more than 100 students altogether. Two or three questions on the exam have a very high error rate. In fact, for two of the questions nearly 100% of the students who took the exam as a final for GN131 answered incorrectly. For some students, these were the only questions they missed. This leads us to believe that some questions should be revised before the next offering of the exam. Other than that, we believe that the placement exam adequately measures a student's spatial abilities and his/her understanding of graphics principles. We intend to continue to use this exam in our placement procedure and to further assess and modify it as deemed necessary.
REFERENCES


BIOGRAPHICAL INFORMATION

SHERYL A. SORBY received a PhD in Mechanical Engineering from Michigan Technological University in 1991. She primarily teaches freshman graphics courses and computer aided design. She currently is an Associate Professor in the Civil and Environmental Engineering Department at MTU and the Director of General Engineering. Her research and teaching interests are in the areas of spatial visualization and experimental mechanics.

MICHAEL F. YOUNG is an Instructor in Michigan Tech University's Mechanical Engineering-Engineering Mechanics Department. He is also a graduate of Michigan Tech (B.S.) and the University of Utah (M.S.). His areas of expertise include Computer Aided Design software, engineering graphics, industrial ergonomics and occupational biomechanics.