Using First Year Engineering Graphics Course for Student Outcomes and Assessment

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Abstract

This paper shows how a first year course in engineering graphics has been used for attaining ABET student outcomes and assessment, as well as to learn lessons for continuous improvement. The following student outcomes were used: (d) ability to function on multidisciplinary teams, (g) ability to communicate effectively, and (k) ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. For each student outcome items were selected from the course syllabus that address the student outcome, as well as the items used to evaluate if the student outcomes had been attained. The course objectives included, among others, helping students understand the role of engineering graphics in the engineering design process, understanding and applying the engineering graphics language and tools of the engineer, creating design sketches using pencil and computer, using reverse engineering to create working drawings, detail and assembly drawings. Students were taught freehand sketching, visualization, mechanical drafting, CAD using AutoCAD, Creo Elements/Pro Engineer and SolidWorks. They were then organized into teams and assigned to choose individual team projects on reverse engineering of mechanisms that had design intent. Students were tasked to make oral presentations to communicate the design intent. These presentations can be in the form of power point slides or equivalent, or posters. Student assignments as well as team projects were graded by the course instructor. Students also carried out peer evaluations of team members. Direct and indirect assessments were used to evaluate student outcome attainment. The level of attainment of the student outcomes was compared to the target levels and action steps identified for further improvements.

Introduction

The objectives of this paper are:

- To demonstrate how Engineering Graphics (EG) can be used for attaining
  - ability to function on multidisciplinary teams;
  - ability to communicate effectively;
  - ability to use techniques, skills, and modern engineering tools necessary for engineering practice.
To learn lessons for continuous improvement.

**Literature Review**

Teamwork has always been a common element in engineering learning. Two learning outcomes result from teamwork: outcomes relative to course content (product outcomes), and outcomes relative to team skills and participation (process outcomes). Engineering faculty is generally comfortable in enhancing learning in the content area. However, enhancing learning in the team skills is quite often unfamiliar (Agoki, Clark, Behnke, and Lee, 2007). To be cooperative a group of students require positive interdependence, promoting each other’s learning and success, holding each other personally and individually accountable to doing a fair share of work, appropriately using interpersonal and small group skills needed for cooperative efforts to be successful, and processing as a group how effectively members are working together (Smith, 1995).

The freehand sketches and the Pro Engineer drawings demonstrated that a mixed group of students (college freshmen, sophomores, seniors; high school and home schooling) who have no drafting experience prior to enrolling for an engineering graphics course can learn and develop basic skills in graphics communication within an academic semester. Also, through this course students demonstrated that they could work in a team and subgroups to accomplish a task/project provided they get clear instructions of what is expected of them, and that they have effective leadership by one of them and have mastered the basics of engineering graphics (Agoki, Clark, Behnke, and Lee, 2007).

The following lessons with respect to skills development in technical writing, presentation, and teamwork were learned (Agoki, Clark, Behnke, and Lee, 2007):

- That the instructor and the client should be readily available for consultation.
- That when students are assisted, it facilitates them to complete assignments; even the complex ones.
- The instructor and the student Project Team Leader should balance work distribution and cater for the best students as well as slow learners.
- Incorporating a real life experience helps to bring course material to reality and aids in skills development and affords an opportunity for students who are engineers-in-the-making to have a foretaste of how engineering teams work in real life situations. Such experiences help to concretize concepts that would otherwise remain abstract.
- Pizza helps create a hospitable working environment and helps to motivate students in their class work and completion of assignments.
- Students will complete assignments and do their best when they know that the work will contribute to the final grade.
There has to be fallback measures in case students do not complete work that has due dates promised to the client. Delays in delivery can cause delays in shipment with severe financial implications.

As part of the evaluation students made the following comments with respect to the course Engineering Graphics: “The class teaches good teamwork, very good team work on the whole” (Agoki, Ng, and Johnson, 2007). Agoki, Ng, and Johnson (2007) concluded that first year courses, Introduction to Engineering and Engineering Graphics, are excellent vehicles for initiating students into engineering and developing their skills in technical writing, oral communication, team building, creativity, analysis and synthesis in the overall engineering design process; through real life projects.

Andrews University has stipulated that “No course with a grade below C- may count toward a major or minor” (Andrews University, 2011-12), and the following target levels have been set for the Engineering Program for the attainment of student outcomes: 85-100% Good, acceptable; 70-84% Fair, improve; <70% Poor, unacceptable (Andrews University Engineering Program, 2009).

**Methodology**

For each Student Outcome (SO) items were selected from the course syllabus that addressed the SO, as well as the items used to evaluate if the SOs had been attained. The items from the syllabus that addressed SOs included team projects using reverse engineering problems, course objectives, assignments, exercises and labs. The items used to evaluate if the SOs had been attained included the instructor’s direct assessment of the team projects, students’ peer evaluation of team members; oral presentation of team projects, models, drawings, and posters; examinations on visualizations, AutoCAD, SolidWorks and Creo Elements/Pro Engineer.

The course objectives included, among others, helping students understand the role of engineering graphics in the engineering design process, understanding and applying the engineering graphics language and tools of the engineer, creating design sketches using pencil and computer, using reverse engineering to create working drawings, detail and assembly drawings.

Students were taught freehand sketching, visualization, mechanical drafting, CAD using AutoCAD, Creo Elements/Pro Engineer, and SolidWorks. They were then organized into teams and instructed to choose individual team projects on reverse engineering. The students were required to identify the design intent in the product. For each project, the following was required: disassembling, measuring, and sketching each part; creating 3-D models or engineering drawings of each nonstandard part, with dimensions; specifying standard parts, using engineering catalogs; creating an assembly drawing with parts list; creating a written report that summarized the project, listing the strengths and weaknesses of the product they reverse engineered, comments on the
serviceability of the product, recommended changes to the design, with special reference to Design For Manufacturability (DFM) principles (Bertoline, Wiebe, Hartman and Ross, 2011).

Students were further tasked to make oral presentations to communicate the design intent. These presentations could be in the form of power-point slides or equivalent, or posters.

Student assignments as well as team projects were graded by the course instructor. Each student peer evaluated a team member using the evaluation instrument developed by the instructor. Each student completed an indirect assessment to evaluate how well they thought they had attained the SO. Both the direct and indirect assessments were used to evaluate SO attainment. The level of attainment of the SOs was compared to the target levels that had earlier been set and action steps were identified for further improvements.

Results and Findings

Peer Evaluation of Ability to Function in Multidisciplinary Teams: Below is a report summary of 31 respondents out of a class of 36 who worked in groups of 3 to 4 students to develop the ability to function in multidisciplinary teams. Table 1 presents the team member knowledgeability and technical competence, Table 2 shows the individual team-member characteristics, Table 3 gives the recommendations about the team member on the project, Table 4 summarizes the results of the positive experience with the team member on the project, and Table 5 displays the results of the negative experience with the team member on the project. Figure 1 presents the results of the peer evaluation of team-member characteristics. Figure 2 shows the comparison of the grades of peer versus instructor assessment of the team projects.

<table>
<thead>
<tr>
<th>Level</th>
<th>Performance Indicator</th>
<th>Below Average 2 (% of Class)</th>
<th>Average 3 (% of Class)</th>
<th>Above Average 4 (% of Class)</th>
<th>Superior 5 (% of Class)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledgeable/</td>
<td></td>
<td>3%</td>
<td>13%</td>
<td>55%</td>
<td>29%</td>
</tr>
<tr>
<td>Technically Competent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Individual team member characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Below Average 2 (% of Class)</th>
<th>Average 3 (% of Class)</th>
<th>Above Average 4 (% of Class)</th>
<th>Superior 5 (% of Class)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creative</td>
<td>0</td>
<td>20%</td>
<td>48%</td>
<td>32%</td>
</tr>
<tr>
<td>Responsible</td>
<td>0</td>
<td>13%</td>
<td>39%</td>
<td>48%</td>
</tr>
<tr>
<td>Decision maker</td>
<td>0</td>
<td>19%</td>
<td>55%</td>
<td>26%</td>
</tr>
<tr>
<td>Organized/Prompt/Dependable</td>
<td>3%</td>
<td>10%</td>
<td>32%</td>
<td>55%</td>
</tr>
<tr>
<td>Valuable/loyal</td>
<td>0</td>
<td>6%</td>
<td>39%</td>
<td>55%</td>
</tr>
<tr>
<td>Capable of leadership</td>
<td>3%</td>
<td>23%</td>
<td>35%</td>
<td>39%</td>
</tr>
<tr>
<td>Friendly</td>
<td>3%</td>
<td>0</td>
<td>29%</td>
<td>68%</td>
</tr>
<tr>
<td>Honest/Reliable</td>
<td>0</td>
<td>0</td>
<td>39%</td>
<td>61%</td>
</tr>
<tr>
<td>Initiative &amp; Drive</td>
<td>3%</td>
<td>6%</td>
<td>32%</td>
<td>59%</td>
</tr>
</tbody>
</table>

Table 3: Recommendations about team member on the project

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>NO (% of Class)</th>
<th>YES (% of Class)</th>
<th>Target Level (%)</th>
<th>Remarks on Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pay Raise</td>
<td>10</td>
<td>90%</td>
<td>85-100</td>
<td>Good, acceptable</td>
</tr>
<tr>
<td>Management Position</td>
<td>26</td>
<td>74%</td>
<td>70-84</td>
<td>Fair, improve</td>
</tr>
<tr>
<td>Serve with Again</td>
<td>10</td>
<td>90%</td>
<td>85-100</td>
<td>Good, acceptable</td>
</tr>
</tbody>
</table>

Figure 1: Peer evaluation of team members’ characteristics
### Table 4: Results of positive experience with team member on the project

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>% of Class</th>
<th>Target Level (%)</th>
<th>Remarks on Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium to High Pay Raise Level</td>
<td>87</td>
<td>85-100</td>
<td>Good, Acceptable</td>
</tr>
<tr>
<td>Warm</td>
<td>94</td>
<td>85-100</td>
<td>Good, Acceptable</td>
</tr>
<tr>
<td>Energetic to Indifferent</td>
<td>100</td>
<td>85-100</td>
<td>Good, Acceptable</td>
</tr>
<tr>
<td>Compatible</td>
<td>81</td>
<td>70-84</td>
<td>Fair, Improve</td>
</tr>
<tr>
<td>Enjoyable/Neutral to work with</td>
<td>100</td>
<td>85-100</td>
<td>Good, Acceptable</td>
</tr>
<tr>
<td>Open minded/Flexible</td>
<td>93</td>
<td>85-100</td>
<td>Good, Acceptable</td>
</tr>
<tr>
<td>Mature and Professional/Showing Potential</td>
<td>100</td>
<td>85-100</td>
<td>Good, Acceptable</td>
</tr>
</tbody>
</table>

### Table 5: Results of negative experience with team member on the project

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>% of Class</th>
<th>Target Level (%)</th>
<th>Remarks on Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domineering</td>
<td>19</td>
<td>16-30</td>
<td>Fair, improve</td>
</tr>
<tr>
<td>Low pay raise</td>
<td>13</td>
<td>0-15</td>
<td>Good, acceptable</td>
</tr>
<tr>
<td>Opinionated</td>
<td>7</td>
<td>0-15</td>
<td>Good, acceptable</td>
</tr>
<tr>
<td>Cold</td>
<td>6</td>
<td>0-15</td>
<td>Good, acceptable</td>
</tr>
</tbody>
</table>

### Figure 2: Comparison of grades of peer versus instructor assessment of team projects
The team members provided the following comments about working in multidisciplinary teams:

- “Great partner, teammate spent a lot of time working on the project and was always willing to give 100%.”
- “Was an excellent partner, enjoyable to work with, contributed fairly, and had excellent communication skills.”
- “Great teammate, good knowledge, wants to participate, really enjoyed working with him, had good ideas.”
- “Seemed willing to participate but rarely took the initiative to do something (anything).”
- “Should probably try to communicate with group to move together as a unit.”

As overall assessment, 100% of the team projects obtained a grade of “B” or above. One student did not have a teammate. The actions required included enforcing requirement that all students work in multidisciplinary teams, and addressing students’ comments above; particularly those that were negative with a view to mitigating them whilst enhancing and strengthening the positive ones.

**Ability to Communicate Effectively:** Figure 3 displays per cent of class of the instructor’s assessment of students’ ability to communicate orally, using drawings and to communicate the engineering design intent. Team projects were graded by team members as well as the instructor and subsequently used to assess the attainment of the ability to communicate effectively. Each student was required to make an oral presentation of the role they played in the team project. The oral presentation together with the drawings and models were used to assess the achievement of this outcome for each student. The results of the instructor’s direct assessment of the team projects for the 32 students are detailed below. The students’ ability to communicate orally - using drawings and models to communicate the engineering design intent - was evaluated.

![Figure 3: Instructor’s assessment of students’ ability to communicate orally, using drawings and to communicate the engineering design intent](image)

Legend:
- **Outstanding, 10%**
- **Good, 37%**
- **Adequate, 50%**
- **Failing, 3%**
Overall assessment indicated that:
- 97% of students were able to communicate effectively what they did in their team projects.
- One student did not communicate orally.
- Some groups did not effectively use freehand sketching on their team projects.
- 100% of the team projects obtained a grade of B and above.

The action required was identified to be: To ensure that all students communicate effectively the role they played in the team project and make oral presentation as instructed.

**Ability to Use the Techniques, Skills, and Modern Engineering Tools Necessary for Engineering Practice:** The results from 32 students who responded are detailed below. Figure 4 gives the students’ self-assessment of their engineering graphics skills before and after taking the course. Figure 5 summarizes the students’ self-assessment of their AutoCAD/Creo Elements Pro Engineer/SolidWorks skills before and after taking the course, and Figure 6 shows the comparison of the instructor’s direct assessment to the students’ indirect assessment of their overall grade.

![Figure 4: Students’ self-assessment of their engineering graphics skills before and after taking the course](image1)

![Figure 5: Students’ self-assessment of their AutoCAD/Creo Elements Pro Engineer/SolidWorks skills before and after taking the course](image2)
Discussion

Table 1 and Figure 1 reveal that 97% of the class was peer evaluated to have knowledgeability and technical competence ranging average to superior. This is a positive reflection on the attainment of product outcome (course content). Table 2 and Figure 1 show that for creativity, responsibility, decision making, valuability/loyalty, and honesty/reliability - as individual team-member characteristics – the peer evaluation indicated that 100% of the class attained average to superior; whereas for organization/promptness/dependability, capability of leadership, and initiative plus drive 97% of the class members were judged to be average to superior. Again, these results on team-member characteristics reveal that the team building ingredients were brought to the team project to help in team building, which in turn reflects positively on the attainment of the process outcome. Table 3 reveals that team building was attained as 90% of the class indicated that they would serve with their team members again. In terms of management skills, only 74% were recommended by peers for management positions. This is an aspect that should be focused on for improvement. From Table 4 it can be said that the class had a positive experience in the team projects as shown by the peer evaluation. However, compatibility is an issue that requires consideration for improvement when organizing teams. Table 5 reveals the negative experiences, as peer evaluated, to be “domineering”, not deserving “pay raise”, “opinionated”, and “cold”. Using the target levels set, these negative experiences were well within range except for the “domineering” category that requires improvement. Indeed, the target level should be reviewed with a view to minimizing these negative experiences that could adversely impact team building.

The overall grade for the team projects can be used as a proxy measure for the attainment of SO “ability to function on multidisciplinary teams”. Using peer and instructor assessment all team projects obtained a grade of C- and above (Figure 2). According to Andrews University grade requirement all team projects passed satisfactorily with respect to SO (d), except for the project
carried out by only one student (one-member team not being allowed). For future team projects all students will be required to be in a team consisting at least two members.

For SO “ability to communicate effectively,” Figure 3 shows that according to the instructor’s direct assessment 97% of the students were able to communicate effectively. This attainment is within the 85-100% target level which is “Good, acceptable”. Although one student did not communicate orally, he/she was able to communicate using other means, particularly using EG. The groups that did not effectively use freehand sketching on their team projects lost points on their team project grade as this had been stated as a requirement to enhance communication.

From Figures 4, 5 and 6 the instructor’s and the students’ own assessments indicate that a majority of students enroll for EG with no/poor skills and only a small percentage (less than 10%) say that they come with adequate EG skills with respect to SO “ability to use the techniques, skills and modern engineering tools necessary for engineering practice”. After taking the EG course the instructor’s and students’ own assessments reveal that 94% of the class attained a grade of C- and above; thus meeting the target level of “85-100% Good, acceptable”. The need to expose students to AutoCAD, Creo Elements/Pro Engineer, and SolidWorks has been debated in terms of whether this is not sacrificing depth and proficiency. However, there are arguments in favor of this practice as these three software tools are the ones commonly used in industry and different faculty members have preferences when it comes to modeling for other courses such as machine design, manufacturing, and finite element methods.

A number of lessons have been learned with respect to assessment rubrics, targets, data collection and analysis, among others. These lessons are:

- There is need to have clear and concise rubrics for assessing the SOs. The rubrics should clearly show the performance indicators as well as the proxy measures being used for assessment. These need to be refined continuously.

- There needs to be a basis and rationale for targets set for evaluating the attainment of SOs. Once the targets are set, they need to be reviewed and revised for continuous improvement.

- The assessment data collected need to be analyzed in a simple but clear fashion to facilitate the determination of whether or not the SOs have been attained and to what degree, as well as helping in pointing to the necessary action for improvement.

Conclusions

In conclusion, this paper has amply demonstrated that the First Year Engineering Graphics Course can indeed be used for the assessment of the attainment of ABET Student Outcomes (d) ability to function on multidisciplinary teams, (g) ability to communicate effectively, and (k) ability to use techniques, skills, and modern engineering tools necessary for engineering practice.
as detailed in the paper; and a number of valuable lessons regarding rubrics, attainment targets, and assessment data analysis have been learned for continuous improvement. Further work needs to be directed toward the development of rubrics for assessing SOs, the development of the basis for performance targets, and the development of analytical tools for assessment data.

References