Assessing Student Work in Engineering Graphics and Visualization Course

David Elrod, Michael D. Stewart
School of Civil and Environmental Engineering/George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology

Abstract

Advances in computer technology have led to significant changes in the content of the freshman engineering graphics course. Course topics, textbooks, and software choices differ from one institution to another, depending in part on the programs of study the engineering graphics course serves. In addition, institutions differ in the methods used to assess student learning. A number of authors have presented their work in the area of grading criteria and assessment of student work in the freshman engineering graphics course.

In the latest revision of the engineering graphics course at Georgia Tech, a backward design approach was used to identify goals for student understanding, to establish assessments for measuring student understanding, and to plan instruction. This paper describes the evolution of the freshman engineering graphics course at Georgia Tech, in terms of course content and assessment methodology. The paper includes a statement of learning objectives, an assessment matrix, and examples of student assignments.

Introduction

In 1999, when the Georgia Institute of Technology converted from quarter to semester curricula, the Schools of Mechanical Engineering and Civil and Environmental Engineering joined together to create a common, required, 3 credit hour introductory engineering graphics course for their undergraduates. The course, "Engineering Graphics and Visualization", is co-listed in the Institute's catalog as ME 1770 and CEE 1770. The new course is also required for undergraduates in the School of Aerospace Engineering.

Currently, the institute offers nine sections of ME/CEE 1770 in both the fall and spring semesters, and two to three sections in the summer semester. Facilities limit enrollment to thirty-six students in each section. In the fall and spring, classes meet for two hour-long lectures and a three-hour laboratory session each week. The lectures are taught by a team of faculty. Each laboratory session is led by two teaching assistants. A total of ten teaching assistants support the labs and hold office hours during the fall and spring.

Initially, ME/CEE 1770 was a textbook-based course. Lectures were from presentations that accompanied the required course textbook. Laboratory activities were established to go with the text. Student performance was assessed by grading homework, the student's notebook, two team CAD projects, 2 major exams, a number of laboratory quizzes, and a final exam. All student work was evaluated summatively, as part of the final grade for the course. The grade a student received for the course included evaluations of the student's initial understanding of each new concept.

Prior to the 2002 summer semester, ME/CEE 1770 was revised using the "backward design" approach of Wiggins and McTighe (1998). The approach is a three stage curriculum planning sequence for educators. In the first stage, educators identify the enduring understandings to be learned and retained by students. In the second stage, educators determine what assessment evidence will be collected to document the level of understanding achieved. In the third stage, educators plan instructional activities to enable students to achieve the desired level of understanding. The backward design approach emphasizes the use of "formative assessment": assessment activities designed to provide feedback which is used to modify teaching and learning activities (Black & Williams, 1998).

The remainder of this paper describes: (1)

problems identified in the initial setup of the course; (2) the application of backward design to revise the course; and (3) implementation of the resulting plan by the team of educators (instructors and teaching assistants) at Georgia Tech.

The Initial Course Design – 1999-2002

In the fall of 1999, the fifteen-week course Engineering Graphics and Visualization included four weeks of freehand sketching and eleven weeks of three-dimensional, constraint-based, solid modeling. A textbook (Mabrey, 1997) was chosen, and lectures, activities, and assignments followed the text. Written, graded homework was assigned at the end of lectures and after in-lab activities. At the beginning of most lab sessions, teaching assistants proctored quizzes over material covered in lecture and lab. Two exams were administered: one at the end of the four week sketching period, and the course final exam. Students were required to keep a notebook, which was submitted for grading at the end of the semester. Students participated in two team CAD projects, each of which ended with a graded presentation. In addition, each team submitted a project report at the end of the second CAD project.

During the first three years of ME/CEE 1770 instruction, instructors, teaching assistants, and students identified a number of issues of concern regarding the design of the course. Some issues were the result of overlooking students' lack of prior knowledge. Some were the result of counterproductive assessment techniques.

During the first assigned team project in the fall of 1999, students' lack of prior knowledge became evident. Most students had few team skills. Instructors and teaching assistants scrambled to inject team management instructions into an already full teaching schedule. They delivered handouts and examples about generating timelines, holding meetings, and allocating tasks. Additionally, most students had little or no experience planning, preparing, practicing, and presenting a technical presentation. Initially, the instruction team issued a list of presentation "do's and don'ts" to students, and directed them to "helpful" presentation tutorials.

A number of the assessment techniques used in ME/CEE 1770 from the fall of 1999 through the spring of 2002 were counterproductive. Summative scores were recorded for activities completed during the learning phase, and feedback was slow. A student's first try at applying a new concept, in a homework assignment or quiz, was evaluated as part of the semester grade. Lab homework was submitted one week after assigned, graded by the teaching assistants, and returned to students no earlier than one week after it was submitted. If a student had misunderstood some aspect of a new concept, two weeks might pass before the misunderstanding was revealed. Teaching assistants sometimes returned a quiz and multiple homework sets at the same time. Many students would check the grade received on an assignment without considering feedback comments. Assessments could not be used to modify teaching and learning activities two weeks after the activities ended.

In the fall of 2001, the course content was changed, but the assessment techniques remained much the same. A fifteen week semester started with four weeks of sketching, but the 3D CAD content was reduced so that four weeks of two-dimensional CAD instruction could be introduced. During weeks five through eight, civil engineering applications became the emphasis: e.g., CAD drawings of building plans, elevations, and wall section views. An individual 2D CAD project replaced the first 3D CAD team project. Finally, in the spring of 2002, the course was redesigned, as described in the following section.

Revision by Backward Design

The first stage in the backward design of a curriculum is to identify the desired results. In the context of an engineering curriculum, this means identifying the ideas, concepts, and processes at the heart of the engineering discipline that we want our students to know, understand, and be able to do. For the backward design of ME/CEE 1770, it is important to note that there are no engineering courses as prerequisites, and that the course is recommended for second semester freshmen in ME and CEE, and for first semester sophomores in AE. This course is a pre-requisite for ME courses.

Three ideas, concepts, and processes in the engineering disciplines chosen as worthy of understanding for students of ME/CEE 1770 are:

- Ideas, designs, and manufacturing/construc-

Course Goals		3 Exams	Notebook	2-D CAD project	3-D CAD project	Other
		Forms of Assessment				
Course value		35%	25%	10%	25%	5%
1. Generate and interpret schematics.		X	X			?
2. Sketch pictorials:	a) Oblique	X	X			?
	b) Isometric	X	X			?
3. Sketch multiviews:	a) Principal views	X	X			?
	b) Section views	X	X			?
	c) Detail views	X	X			?
4. Interpret technical drawings, charts and graphs.		X		X	X	?
5. Use 2-D CAD		X	X	X		?
6 Use 3-D CAD		X	X		X	?
7. Work on a team			X			?

Table 1. Assessment Matrix

tion procedures and techniques are communicated by words, numbers, and visual images.

- Freehand sketches and CAD are used to model 3 dimensional objects.
- Engineering tasks are performed by teams

More specifically, after completing ME/CEE 1770, students should be able to:

- interpret technical drawings, charts, and graphs;
- generate and interpret schematics;
- sketch oblique and isometric of objects;
- sketch multiviews of objects, including principal views, section views, and detail views;
- create both 2D and 3D CAD models;
- participate constructively in a team engineering activity;

The second stage of the backward design approach is to determine what assessment evidence is needed to document and validate that the desired learning has been achieved. In ME/CEE 1770, an assessment matrix is issued to the students during the first week of class. The matrix, shown in Table 1, associates the course objectives with the forms of assessment used to evaluate the learning achieved. Note that homework and quizzes are not in the matrix. The assessment item "Other" is present to allow instructors some flexibility in assessment during the semester. For example, if the performance on an exam indicates that a concept has not been adequately delivered, the instructor may engage in another approach to teaching the concept, with a follow-up assessment.

In addition, students are issued a statement of the importance of the notebook as an assessment item. They are provided with a number of resources, including examples and guidelines, to help them maintain a good notebook. They are encouraged to expect regular notebook checks with feedback. The feedback is intended to enable better performance when other formal assessments

Course Goals	Notebook Assessment of Goal
1. Generate and interpret schematics.	Printouts and notes about CAD generated graphics
2. & 3. Pictorial and Mulitview sketching	Drawings of each tpe: oblique, isometric, principal views, scetion views, detail views Written plans for creation of drawings
4. Notebooks will informally assess interpretation of technical drawings, charts and graphs	
5. Use 2-D CAD	Written plans for using 2-D CAD
6. Use 3-D CAD	Written plans for using 3-D CAD
7. Work on a team	Team meeting notes Students individual contribution to the project Teamwork reflection entry

Table 2. Notebook Assessment

are administered. Table 2 is issued to the students to identify which parts of the notebook serve as a formal assessment of each course objective.

The final stage of the backward design approach is to plan instructional activities to enable students to achieve the desired level of understanding. Course activities in ME/CEE 1770 have been adjusted to increase the emphasis on team activities. To provide schedule time for this emphasis, the amount of detailed instruction on CAD commands has been reduced, and limits have been placed on the complexity of the 3D CAD team project. Instead of an entirely open-ended design, the project is limited - the number of parts in the final assembly is limited to between two and four parts per person. In addition, instructors and teaching assistants often help students think about ways to simplify their designs as part of the formative assessment of sketches generated during the ideation phase of the project.

Students now have more personal responsibility for their learning. For example, a 3D CAD task is assigned, a set of potential solution tools is identified, and students are responsible for selecting tools, learning to use them, and explaining why and how the tools were used to accomplish the task.

These changes have provided more time to emphasize and formatively assess the use of team management skills like setting meeting agendas, recording meeting minutes, assigning action items, and defining deliverables.

Implementation

One of the main changes in the design of ME/CEE 1770 is the use of formative assessment techniques to modify the learning process and to provide immediate feedback as students complete assigned tasks. Homework is not assigned for a grade. Lab activities are designed with the expectation that students will finish the activities before the lab period ends. Examples of the application of this approach follow.

During the second week of the semester, students are required to sketch oblique and isometric pictorials of a variety of objects. As soon as they select the first objects they will sketch, teaching assistants begin assessing their efforts.

The teaching assistants are provided guidance for interacting positively with the students as they assess, without telling the students answers to their questions. Students are required to engage in self-assessment. When a teaching assistant determines that a student has successfully completed a sketch of an object, the teaching assistant enters any appropriate feedback comments on the sketch (e.g., "practice engineering lettering", or "construction lines should be lighter"), and initials and dates the sketch. If a student continues to struggle with sketching principles, the teaching assistant recommends that the student make an appointment with a teaching assistant or instructor to go over sketching concepts. Teaching assistants are provided with checksheets to record the results of their assessments. By the end of lab, these formative assessments may be used to alter the teaching/learning process before the next new concept is introduced.

When students are engaged in laboratory CAD activities, they are expected to submit their CAD files for assessment before the end of the lab session. The teaching assistants are encouraged to assess the submittals, using a checksheet provided by the instructors, and provide email feedback by the end of the day after lab. The assessment includes a satisfactory/unsatisfactory evaluation, with a list of common problems observed in evaluating all students' work. Students are allowed to resubmit revisions for one more assessment. If the work is still not satisfactory, an appointment with a teaching assistant or instructor is recommended. Instructors receive a copy of all email evaluations, and the teaching/learning process is modified as necessary.

The following are examples of questions and comments recommended to teaching assistants for facilitating learning:

- To assess understanding:

  General: How's it going? / What have you done so far? / How does this relate to what you've done in class? / What are your plans?

- Responses for the comments:

  I don't know where to start. / I don't know what to do next. / I'm stuck.

  Answers:

  Have you thought about what you might apply from past experience? / What have you been covering in class? / How can you apply what you've done in class? / Show me your plans so far. / Show me what you've done so far. / What do you remember about the discussion of this concept in class? / What did you write in your notebook (during lecture) that might help you proceed?

- For the questions:

  Is this what I'm supposed to do? / Is this right? / Is this what you are looking for? / Is this enough?

  Possible answers:

  Does this answer the question/problem you were assigned?

  Does this approach make sense based on what you've covered in class?

  How does this approach relate to what you've been over in class?

  That is an approach that has merit. Have you considered other approaches? What other approaches have you considered?

  What were you trying to do? Show me your plan.

When a teaching assistant observes a student who has a misconception (e.g., using an incorrect approach), the teaching assistant is encouraged to pose a question that cannot be answered using the student's approach, thus putting the student in "disequilibrium", and forcing the student to think of another approach.

As a result of these changes in implementation, students receive helpful, timely, formative assessments. They assume a greater responsibility for their learning, and have a greater sense of ownership of their education. Often, students identify their own errors before the teaching assistant says a word. The students are expected to keep all trials in their notebooks, writing their observations before correcting their mistakes. Instructors and teaching assistants become aware of misconceptions and learning problems in time to adjust the teaching process.

Conclusions

The course Introduction to Engineering Graphics and Visualization, ME/CEE 1770, is now in its fifth year at Georgia Tech. The course has been revised using the backward design approach of Wiggins and McTighe (1998). Originally a textbook-based course with too much breadth and very little formative assessment, ME/CEE 1770 is now a course with lectures and labs designed to lead students to an understanding of three "big ideas" in engineering:

- Ideas, designs, and manufacturing/construction procedures and techniques are communicated by words, numbers, and visual images.
- Freehand sketches and CAD are used to model 3 dimensional objects.
- Engineering tasks are performed by teams.

Each student enrolled in the course has a greater responsibility for his/her own learning. Timely, formative assessment is used to evaluate and modify the teaching/learning process before summative assessment tools are used.

The use of formative assessment means that ME/CEE 1770 will continue to be modified to improve the teaching/learning process. There is a need to improve the implementation of teaching assistant feedback in modifying instruction. Instructors must incorporate more student reflection time in planned course activities. Currently, a workshop for teaching assistants is under development to educate and train teaching assistants in the education principles used to design the course.

Acknowledgments

The authors wish to thank the Georgia Institute of Technology for having the foresight to establish Academic Professional positions to concentrate on the design and delivery of this introductory engineering course.

The authors wish to thank Arlene Elrod, Program Consultant, The Laser Center, National Science Resources Center, for her assistance with the backward design process.

References

Black, P., & Williams, D. (1998), Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan*, 80(2), 139-149.

Mabrey, R. L. (1997), *Engineering graphics: Principles, standards, and models*, New York: Addison-Wesley.

Wiggins, G., & McTighe, J. (1998). *Understanding by design*, Alexandria, Virginia: Association for Supervision and Curriculum Development.