Implementing a Program of Continuous Assessment and Improvement for a New Sophomore Design Course

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Abstract

When implementing a new course, it is essential to include a program of continuous assessment and improvement. This paper discusses how a program of continuous assessment and improvement was included in the development and initial implementation of a new sophomore design course in the Mechanical Engineering Department at Iowa State University. In the Fall of 1998 the faculty decided to add a new required sophomore design course. The course provides engineering design experience that encompasses the full range of the design process including construction of a working prototype of the final design. There are three major goals of the course:

1) To give faculty an opportunity to interact with mechanical engineering students earlier in the curriculum.
2) To prepare and motivate students to later take technical courses in mechanical engineering.
3) To provide a bridge between the introductory design course of the freshman year and the capstone design course of the senior year.

Additionally, several other ABET Engineering Criteria 2000 goals were identified as course objectives. These included introducing students to professional practice, developing oral and written communication skills, and gaining an understanding of the impact of engineering decisions on society. The following year these general objectives were expanded to specific goals and assignments, and a pilot course was offered. Simultaneously, a program of assessment and improvement was implemented. Initial assessment results were used to measure success of the pilot course against the original course goals and to provide guidelines for scaling the course up to four or five sections a semester.

This assessment included three separate groups. These were a group of 18 students, a faculty group, and an industry group. Developing clear and convincing evidence of the performance of the course was a key concern. This paper discusses the assessment methodology, results, and the changes made during the startup phase of the course.

Introduction

Engineering design is a critical part of an engineering education. This is clearly recognized in the Engineering 2000 Criteria under Basic Level Accreditation, Criteria 3, Program Outcomes and Assessment[1]. In early 1998 the Iowa State University Mechanical Engineering Department faculty reviewed the engineering design related curriculum and decided to add a sophomore design course to strengthen the design portions of the curriculum. With the addition of this course the design sequence includes 1) Introduction to Engineering Graphics and Design, 2) Introduction to Mechanical Engineering Design (ME 270), and 3) a capstone design course. The

Introduction to Engineering Graphics and Design covers the engineering graphics, mechanical dissection, creativity techniques, brainstorming, group dynamics and decision making, and the design process. Additionally it provides a brief design experience in teams. The capstone design experience is an industry-style design experience, covering the entire design process from identification of a need to the final design. The goal of the sophomore design course, Introduction to Mechanical Engineering Design, is to bridge the gap between these two engineering design experiences emphasizing a semester long design experience and the issues of professional practice.

Background

In order to build on the students' frosh class experience and prepare them for technical course work and the capstone design experience, four key aspects of this course were established. These are the following:

- Students will have a design experience that encompasses the full range of the design process,
- Students will build a prototype of their final design,
- Students will continue to develop their written and oral communication skills, and
- Lectures will be presented that describe various aspects of mechanical engineering (e.g. heat transfer, mechanisms, controls) and their impact on the student's project.

The specific goals of this course are the following:

1. The student should be able to identify the relevant design problem and the associated design objectives and constraints.
2. The student should be able to implement various phases of the design process and use different tools and solution methods in each phase in the context of engineering design problems.
3. The student should be able to use a wide variety of creative thinking methods and tools to develop unique, meaningful, and viable design options.
4. The student should be able to incorporate analysis tools into the design process, choosing the correct tools for each aspect of the design process and each type of design.
5. The student should be able to determine the best engineering design that satisfies all implicit and explicit constraints.
6. The student should be able to schedule and plan engineering projects, coordinating disparate groups and tasks to complete the project.
7. The student should be able to actively participate in the design process as a member of an engineering team in a variety of roles.
8. The student should be able to apply an understanding of ethics, patents, and legal issues to the design process.
9. The student should be able to understand the technological, environmental, and economic ramifications of engineering products and the impact of engineering decisions on the design process.
10. The student should be able to assess the functional fitness of the final prototype to meet the design criteria.
11. The student should be able to present technical material concisely and clearly using appropriate written, oral, and graphical techniques.
12. The student should be able to plan for continuous improvement through future design iterations.

Simultaneously with the implementation of the course, a system to continuously assess and improve the course was established to measure progress towards meeting these goals.

Initial Implementation

In the first semester Introduction to Mechanical Engineering Design was offered as an experimental class with a carefully selected cross section of 20 students. As shown in Table 1, this test section of the class had higher test scores, higher grades, and a higher percentage of minorities and females than the overall mechanical engineering student population. Students with higher test scores and grades were chosen because it was felt that they would be more capable of handling the potential bumps in a new course. A higher percentage of women and minorities was chosen so that a representative group of women and minorities would be available to critique the class goals and performance. Two students dropped the course; a foreign national dropped the course in the second week because he lacked the written communication skills needed, and a white male dropped the class for reasons unrelated to the class. The students were divided into four groups. The students were allowed to pick one person that they wished to work with. Other than this, the groups were assigned randomly.

	Class	Overall
GPA	3.5	2.9
ACT score (composite)	28.5	26.4
Women	30%	8%
Minorities	20%	7%
Number	20	843

Table 1. Student population characteristics.

The class met seven hours each week, three two-hour labs (MWF) and one lecture period (T). This time was allocated as follows:

- Monday - Each group met with the instructor once per week for 20-30 minutes. In this time group progress was reviewed, questions answered, and advice on the design project given. The meeting was based on a student prepared weekly memo that included the number of hours worked and the projects these hours were spent on. The remainder of the time was unstructured time for students to work on assignments and the design project.
- Tuesday - Approximately half of the lectures were provided by the faculty on mechanical engineering topics (e.g. thermodynamics, manufacturing, controls, mechanical systems) taught primarily from a qualitative perspective. The other half of the lectures were provided by the student groups and were based on the material in the class book.
- Wednesday - Approximately one-quarter of this time was spent on student lectures. The remainder of the time was unstructured time for students to work on assignments and the design project.
- Friday - This was unstructured time for students to work on assignments and the design project.

In addition to the student lectures (2-3 per group) and the design project, there were six additional assignments and one exam. The assignments were designed to give the students the additional skills needed to complete the design project and improve their communication skills. These included numerical assignments, a fabrication assignment using the shop to manufacture a screwdriver or hammer, mechanical dissection, and thinking/research assignments. In general the assignments were open ended without specific answers and without additional in-class instruction. All the class assignments were given to the students in the first two weeks of the class and were due much later in the semester. The exam covered intellectual property and ethics. The overall structure of the class provided the students with a large degree of freedom in a studio teaching environment. The class was graded in a traditional manner with grades assigned for each assignment, the exam, and the design project. The design project was one-half of the overall grade.

The Assessment Process and Results

At the same time that the initial ME 270 was being developed an assessment process was also developed. The goal of this assessment process was to provide an established, ongoing process of assessment and change for the ME 270 class. The assessment consists of three different groups, a student group, a faculty group, and an industry group. In the pilot semester the student group was comprised of the student members of the class. The primary form of assessment was three discussion/seminar sessions in which each of the student groups considered the goals and progress of the class and provided comments and a final questionnaire. Following the pilot semester the student group will be comprised of former and current ME 270 students who review the class goals and the progress towards these goals twice a semester. A faculty group of three professors met approximately every two weeks to review the progress of the class and written assignments, and to plan for the full implementation of ME 270 with 150 students and 5 sections each semester. The Mechanical Engineering Advisory Council provided the industry group. The Mechanical Engineering Advisory Council consists of 16 engineers from industry who meet twice a year and advise the ISU mechanical engineering department. Each group provided a different type of input and particularly in the case of the industry group the assessment process needs to be refined to ask specific questions and encourage specific recommendations.

<u>Faculty Group</u> - The faculty group focussed primarily on the issues of implementation, student time, and grading. The specific faculty observations included the following:

- The numerical assignment was based on teaching the students how to use a commercial equation solver and providing a set of exercises to help the students develop their skill using the software. This used approximately one and one-half week of student time. However, students did not develop sufficient expertise with the software. As a result they were not comfortable using the equation solver in their design project analysis. Instead they used tools (e.g. spread sheets) that they were familiar with prior to entering the class. Either the students needed more assignments requiring the use of an equation solver, more time needed to be spent on training, or both.
- Although students had learned how to use a commercial CAD package in their freshman year, they did not use CAD drawings in their design. Instead they used hand drawings and verbal description to implement their designs.
- Grading was a challenging issue. Because each assignment was graded on a traditional A - F basis, some students spent excessive periods of time completing the assignments, particularly the shop work, in order to achieve higher levels of skill than were expected in the class. In many of the assignments, the goal was to provide the student with exposure to the item (e.g. how to use a vertical milling machine), not to achieve mastery. With exposure to the item, students would then be able to use the skill or item in their final design.

- Although the students' grammar skills were generally acceptable, they lacked the ability to clearly summarize their work and to choose the technical data needed to support the conclusions they arrived at. In general the writing seemed more like English class essays or creative writing than engineering report writing.

<u>Industry Group</u> - The industry group was provided with the overall goals for the class, the class syllabus, written descriptions of the design project and homework assignments, and two completed sets of homework for the class. Because this was the first semester that class was offered, no design projects were available for review. Additionally, the industry group met with members of the class and discussed the class projects and goals. The industry group was asked to consider three questions regarding the ME 270 class.

- Are the goals appropriate?
- Do the assignments support the goals?
- What other assignments should be included?

The industry group was enthusiastic about the course and thought that the strengths of the class were the following:

- The course can build a hunger in the students for more technical education by providing a realistic engineering design experience.
- The open-ended assignments help students learn how to think through and approach technical problems.
- The students were free to schedule their time and learn how to manage a variety of tasks in a group environment.

However, apart from commenting the class would be challenging to teach and suggesting that focusing more attention on engineering in consumer goods that the students have used, the industry group provided no specific recommendations for improvement.

<u>Student Groups</u> - The student assessment was comprised of three discussion/seminar sessions in which each of the student groups considered the goals and progress of the class and provided comments and a final questionnaire. In general the results of the questionnaire were very similar to the results from the discussions/seminars. In the questionnaire the students were asked to grade each of the assignments from 1 - 5 in two areas, the usefulness of the assignments and their enjoyment of the assignment, with 1 being poor, 3 being neutral and 5 excellent. The results of this grading are presented in Table 2. Additionally, students were asked about the completeness of the design experience, the weekly meetings, the usefulness of the book, the usefulness of the student conducted lectures, the open-ended approach of the assignments, the class layout, and the importance of the exam. 16 of 18 students responded to the questionnaire.

As shown in Table 2 the initial writing assignment was poorly received and found not to be useful. All assignments had a formal writeup of 1-5 pages. Additionally, the design project had 3 required formal reports, the proposal, the progress report, and the final report. However, the students did not feel they were adequately prepared for this writing. This mirrors faculty concerns about student writing. The mechanisms assignment faired poorly because of the lack of connection of the assignment to the rest of the course and the design project. Only 4 students had operated shop equipment, (e.g. a lathe, drill press, or mill) prior to the class, and 4 had not used a power hand tool. Based on this, the enthusiasm for the shop portion of the class is not surprising.

Title	Description	Usefulness	Enjoyment
Writing	Technical writing assignment to assess writing skills.	2.4	2.9
Analysis	Introduction to commercial equation solving software	3.4	2.9
Shop	Manufacture a hammer or screwdriver in the shop using vertical mill, lathe, drill press, etc.	4.5	4.7
Gummies	Determine the manufacturing processes and engineering involved in the manufacture of gummy candies. This was followed up by a trip to a candy manufacturing plant.	3.3	3.8
Stove	Mechanical dissection of a small backpacking stove. The goal is to determine how it works and to identify how it could be improved.	3.9	4.3
Mechanisms	Calculation of a simple four-bar mechanism.	2.4	2.0
Presentations	Presentation of case histories of engineering errors and chapters from the text.	3.6	3.4

Table 2. Student assessments of class assignments, 16 of 18 students reporting. 1 is poor, 3 neutral, 5 excellent.

Other results from the questionnaire included the following:

- 10 of the students noted that a stronger emphasis on CAD would be a useful addition to the course, 4 students disagreed with this, and 2 did not comment on the use of CAD.
- 10 of the students felt the text helpful in the design course, 4 students disagreed, and 2 did not comment on the text.
- All 16 students felt the weekly meetings were useful, with about 1/4 of the comments being similar to statements like "the meetings were essential to the course" or "the best part of the course."
- The open-ended assignments were well accepted with 12 students saying they were just right, 1 student stating they were too vague, 2 students stating they were too directed, and 1 student not commenting.
- All 16 students found the layout useful and no suggestions for improvement or negative comments were made.
- All 16 students were in favor of the exam on intellectual property and professional ethics.
- 9 of the 16 students stated that more training in technical writing was needed; the other 7 students did not comment on technical writing training.
- 4 of the 16 students requested that training in presentation skills be included in the course; the other 12 did not discuss presentation skills.

The student concerns with CAD were similar to those of the faculty. Although CAD usage was not discouraged and students could have used it, they did not for reasons that are unclear. Again there was a significant concern about written communication skills. There were no concerns about the time invested in class or the overall work, which was an average of 10-11 hours per week per student from the weekly reports.

Changes Implemented

Based on the first semester of Introduction to Mechanical Engineering Design course and associated assessment process, several changes are being made. Several changes are being made to the assessment process to gain a deeper and more critical review of the course objectives and results by the industrial review group. The lack of detailed comments by the industrial review group is the result of several factors. These include 1) the size of the group, 2) the review was a single item on a larger agenda, 3) the questions asked were too general, and 4) more time was needed for the review. To allay these concerns several changes are being implemented. These are the following:

- A separate smaller group of approximately 4 members will be used for the review; this will be a subset of the Mechanical Engineering Advisory Council. This group will review the overall design course performance of the department in a one-day, once a semester review.
- The committee will be provided with specific questions to answer about specific assignments and the design project. They will provide both numerical input and written input to specific questions and issues.
- The final report of the design projects for the previous semester will be reviewed.

Several changes in the class are being implemented. These are the following:

- The numerical analysis assignment is being dropped. The investment of time exceeded the benefit, and students have many other opportunities to learn these skills.
- The assignments and design project are being revised to require the use of CAD drawings, providing a tie to the frosh design course and further developing the students' skill.
- A rapid prototyping portion is being added to the four-bar mechanism assignment. This will provide students with the opportunity to realize their mechanism analysis and design.
- The grading of the course is being revised to a portion that is performance based (40%) and a portion (60%) that is based on contract grading. The performance based portion includes the final design, the final design report, and the exam on intellectual property and professional ethics. The majority of the remaining homework assignments and design assignments will be graded on an acceptable/not acceptable basis.
- Three class hours of teaching on technical writing have been added. The specific emphasis will be on the need to clearly identify the key elements of the technical material being presented and how to summarize these clearly.
- In addition to the rapid prototyping assignment, it is planned to include CNC tooling in the class curriculum.

The primary challenges in this course are 1) to motivate students to do the numerical analysis that they are capable of and 2) to ensure that the expectations of class can be fulfilled in a reasonable amount of study time. Although the students have not yet completed the technical course work they are still capable of some numerical analysis. Ways to include this are still being considered. Changing course priorities and assignments requires that changes not mean increased commitment of student time but better use of the available time. This is being carefully monitored by the faculty.

Summary

Iowa State University has implemented a new sophomore design course. As a part of this implementation, a program of continuous assessment and improvement has been developed. This process is similar to the engineering design process. Based on the results of the first semester, several changes have been implemented. These changes 1) include more emphasis on teaching the fundamentals of technical writing, 2) changes in the grading scheme, and 3) tying the assignments more closely to the design project.

Bibliography

1. Engineering Criteria 2000, 3d ed., Accreditation Board for Engineering and Technology, Maryland, December 1997.

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