A Problem Based Learning Approach for Freshman Engineering

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Abstract:

The South Dakota School of Mines and Technology began a revision of the freshman engineering curriculum in 1997. Beginning with a pilot program of 25 students, the program is now required for virtually all first-year engineering students. The program, FC 2000, utilizes a project -based learning approach and features student teams to integrate material in general engineering, mathematics, science and English. Small projects (2-3 per semester) are designed to give students an exposure to engineering design in a variety of engineering disciplines. Project components include designing and conducting experiments, analyzing data, and presentation of technical data. In this paper we present a model for the first year curriculum, preliminary assessment results, and plans for future integration.

Introduction

Over the last two decades, industry has experienced dramatic shifts in corporate philosophies which now center on quality and customer driven strategies. As a response to this shift in industrial practices, calls for greater accountability in higher education have become more strident than ever. Consequently, external economic, political, and industrial forces led the Engineering Accreditation Commission to create and adopt ABET Criteria 2000, which refocuses the accreditation process on what students have actually learned, rather than on what they have been taught [1]. This is a bold move on the part of the EAC and holds great promise to promote curricular innovation and continuous improvement in the engineering education process.

Beginning in the 1995 academic year SDSM&T faculty taught a one-credit, elective course, GE 197, which served primarily to allow students to explore the various engineering majors available on campus. This course was expanded in the following year with a pilot of 25 students and included to the career exploration aspect project-based learning based upon team projects. Throughout, technical communication skills have been emphasized as well as data analysis and interpretation. The current curriculum, called Freshman Curriculum 2000 (FC 2000), consists of two two-credit courses each with a laboratory component. Starting in the fall semester 1999, the program was expanded to virtually all freshmen engineering majors and had approximately 250 students were enrolled in the FC 2000 curriculum.

FC 2000 Goals

In this paper we present a model which addresses some of the areas of cognitive development within the context of engineering and science education. The model utilizes student teams and a problem-based learning approach to solve simplified versions of realistic problems posed in engineering and science. The program, Freshman Curriculum 2000 (FC 2000), uses semester long mini-projects to integrate curriculum in engineering, math and science. The stated goals for the program include the following:

1. improved problem solving skills, critical thinking skills, and communication skills compared to traditional engineering and science curriculum;
2. an increased ability to integrate and appropriately apply technical skills with the fundamentals of math and science;
3. an increased ability to participate in effective teams;
4. an increased competence in applying technology for effective analysis, design, and communication;
5. an increased motivation for self-responsibility, life-long learning, and self-development of a person of good character.

Integration

An effective way to demonstrate interrelationships among different disciplines is through the integration of two or more courses. Such a concept is not altogether new and is currently being practiced in a number of engineering schools (see for example [2], [3], [4]). In the FC2000 curriculum, topics in general engineering were integrated with English and general sciences (i.e. Chemistry and Physics). In addition, relevant history associated with notable people in engineering and science were integrated as well. It was found that such integration of numerous disciplines was much easier to implement in the initial 25 student pilot of the program [5] than when the number of students increased to 250.

Increased integration of numerous courses remains one of the goals of the program. As a guideline, a set of rubrics using a meta-assessment approach [6] were developed for the areas of communication, problem solving, and team building. A sample rubric for the area of general problem solving is shown below in Figure 1.

ABET Criteria 2000 Criteria: **Problem Solving**				
Behavioral Objectives	Performance Benchmarks Freshman	Sophomore	Junior	Senior
Problem Definition	given scenario identify general prob. statement	open-ended scenario, be able to id prob. stmt.	work with client to identify prob. statement	work with client messy data to id prob. statement
Identify Constrains & Alternatives	identify some alternatives	identify complete set of alternatives	identify altern. & set of constratints	be able to qualify alternatives
Data Collection & Analysis	collect data & analyze given techniques	select appropriate analysis methods for data	given problem collect data & analyze	determine approp. methods for & collect & analyze data
Solution/Evaluation	Identify a solution	Identify several solutions	Identify solutions & evaluate	Qualify solutions by ethical & social impact
Implementation	build small design projects	paper implement for complex designs	implementation criteria for client	work with client to implement solution

Figure 1. Performance Rubric for Problem Solving.

In addition to building connections in the curriculum through the use of integration, the team felt it was important to structure the curriculum in such a manner that it incorporated the best practices in engineering and science education. Specifically, the team felt the curriculum should incorporate active project-based learning, collaborative learning, critical thinking, technology, and writing across the curriculum (see [7], [8], [9] for additional information). Review of retention data indicated that a significant portion of first year engineering students leave the university system following the first or second semester due to a lack of preparatory skills, poor study skills, or an inability to make the necessary commitments to be able to succeed in an engineering curriculum. Consequently, it was also decided that the curriculum should help students develop the necessary habits required to be successful as an engineer. Dr. R. Landis provides a number of useful exercises which worked well for this purpose [10]. To incorporate these elements, student teams were developed to work on several design projects throughout the semeste. These projects reflected components of the various engineering disciplines which participate in the FC 2000 curriculum. For example, one project involved the analysis of flow of water from a tank and an historical overview of Evangelista Torricelli. The remaining elements, including communication components, technology, teaming and critical thinking, were integrated around the central concept of the design projects.

Learning skills and engineering orientation were provided on an as needed basis. A conceptual diagram for the program is shown below in Figure 2.

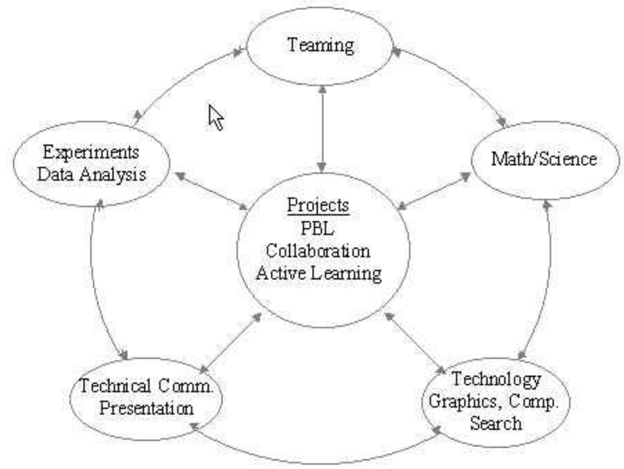

Figure 2. FC 2000 Concept Map.

Technology-Enabled Learning

Students conducted literature and database searches directly from the classroom. In addition, by the end of the first semester course, students had considerable experience with using e-mail to attach and retrieve documents, web authoring, conducting a technical literature search, performing computerized data collection, and using spreadsheets to analyze data and perform numerical analysis. The second semester included a strengthening of these skills and provides for additional laboratory experiences in using technology for technical presentations and graphics including three dimensional (3-D) solid modeling. The latter component culminated in a student project where teams modeled in 3-D each of the campus buildings using blue prints and physical measurements to complete their model.

Freshmen Interest Groups

In the initial pilot program, all students assigned to FC 2000 were grouped together on common floors in the campus dormitories as part of a freshmen interest group (FIG). The freshmen interest group allowed the team development process to continue outside the confines of the normal classroom through normal social interaction. Intermediate feedback through focus groups, small group instructional diagnosis (SGID), and classroom observation indicate that freshmen interest groups provide a positive student experience towards teaming and collaborative learning. Upon expansion of the program in the fall semester 1999 it was found that it was logistically difficult to implement the FIG concept with all students. Like several of the pilot program components, use of FIGs with the entire FC 2000 student population remains as a team goal.

Evaluation and Assessment

A multi-assessment plan has been devised to help determine the impact FC 2000 has on student learning. In the pilot stage, assessment consisted of defining a cohort of students who participate in the program and similar cohort of students who would serve as the control group. The control cohort is comprised of students who are similar to the experimental cohort in that the control cohort had the same number of students and was randomly selected from the same list from which the experimental cohort was drawn. The ratio of students by gender and race was roughly equivalent. Both groups had approximately the same ACT scores and entering requisite skills. Initial results indicated that students in the experimental cohort performed better academically, had a higher retention rate, and were generally more satisfied with the freshmen experience.

Now that virtually all engineering freshmen participate in FC 2000, assessment calls for longitudinal tracking of student cohorts, assessment of student attitudes, portfolio assessment of student writing and presentations, faculty assessment, and some classroom assessment for identifying growth in team and problem solving skills. The latter assessment process is on-going. Table 1 below provides a summary of FC 2000 goals as well as the associated assessment instrument and the timing for assessment activities. In Table 1 AS refers to the campus Academic Services office, which is in charge of several of the assessment components.

Table 1. FC 2000 Assessment Activities

FC 2000 Assessment Activities

Instrument	Process/When	Goals
Longitudinal Tracking	AS/Start Each Semester	2, 3, 5
Attitudinal Assessment	AS Administers U. Pittsburgh scores Sept. 97, April 98	1, 2, 3, 4
Portfolio Assessment	AS collects portfolios Nov. 97, April 98 ASC selects 5 each group May 97 Assessment team evaluate	1, 2, 5
Faculty Assessment	AS distributes survey to appropriate faculty March 98	1, 2, 3, 4, 5
Classroom Assessment	Faculty ongoing	Intervention 3, 5

The attitudinal assessment in Table 1 is an instrument developed by the University of Pittsburgh and utilizes student attitudes to measure 13 different attitudinal factors related to different curricula and pedagogical approaches, [11], [12]. The instrument has been widely tested and is statistically both reliable and valid. Cluster analysis is used to measure positive and negative trends in the 13 different factors representing student attitudes. For additional information related to this instrument and other assessment practices, the interested reader is referred to the following references: [6], [11], [12], [13], [14], and [15].

While it will be years before there is sufficient assessment data to determine the relative long-term impact FC 2000 has on student learning, initial results indicate the program is having a positive impact on both student learning student attitudes towards engineering and science education. Compared to the control cohort, students participating in the FC 2000 program responded positively to the program, to their intended major, and towards the practical application of math and science in engineering design. Of students entering the program, 85% remained within the university system and almost all chose to participate in the second semester despite a few departmental conflicts and loss of credit. Finally, the program also has attracted industrial interest and support. Feedback from alumni and industrial partners has, thus far, been overwhelmingly positive. For example, alumni groups from Boeing and Caterpillar have met the FC 2000 students via the campus telecommunications network to have real-time teleconferences.

FC 2000 Future Directions

Future directions for the FC 2000 curriculum involve inclusion of many of the components from the initial pilot program that have been lost upon expansion. Specifically, integration/linkage of Freshman English with sections FC 2000 curriculum will occur during the fall semester 2000. Similar linkages are anticipated in coming semesters with Freshman Math, Chemistry and Physics. As discussed earlier, expansion of the FIG program is also a future goal for the FC 2000 curriculum. Finally, the FC 2000 faculty team view the FC 2000 curriculum as the cornerstone of the assessment loop needed toward successful accreditation under the ABET 2000 criteria, and hence future efforts will be given toward utilizing the FC 2000 curriculum to meet this challenge.

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