Challenges in Teaching Chemical Engineering Capstone Design

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Introduction

Many chemical engineering programs are striving to meet the challenges posed by various requirements for producing desired outcomes in the senior year capstone design course. At Prairie View A&M University (PVAMU), the approach previously used, in line with those of other institutions, involved multidisciplinary teams from the disciplines in the College of Engineering, which was believed to be a strength [1-3]. The main challenge of this approach was the identification of appropriate problems that present suitable learning vehicles with the required content and challenge for each the undergraduate students comprising each team [3]. Under the new ABET 2000 accreditation criteria which focus on learning outcomes (criterion 3: learning outcomes *a* through *k*), the chemical engineering program at PVAMU saw a need to move towards discipline-focused capstone projects. This paper examines the difficulties facing such a transition, methods undertaken to accomplish this change, and the impacts observed.

ABET 2000 Compliant Capstone Design Course

The accreditation body[1] is reported to view the quality of senior design projects as a check of the health of programs that lead to the undergraduate degree since well researched senior design projects provide the complete ABET 2000 learning outcomes *a* through *k* [4]. A recognized weakness of the multidisciplinary team approach at PVAMU prior to an ABET accreditation visit was the difficulty in demonstrating that members of the team applied the depth, detailed knowledge of the discipline, and skills acquired in earlier coursework, thereby meeting the learning outcomes.

The Department of Chemical Engineering started addressing the weakness with a transition from multidisciplinary teaming to discipline-focused teams in the Fall 2004 semester. Part of the summer of 2004 was therefore, spent identifying projects with sufficient depth and breadth to satisfy the ABET Professional Component criterion. A comparison of multidisciplinary and discipline-focused team approaches is presented in Table 1.

Table 1: Comparison of multidisciplinary and discipline-focused teams

Team type	Advantages	Relevance to ABET 2000	Disadvantages	Relevance to ABET 2000
Multidisciplinary	A better reflection of the work environment	Low	Difficulty in identifying projects with depth and breadth for all team members	High
Discipline-focused	Projects provide depth and breadth and application of knowledge from earlier course work for all team members	High	Work place type teaming experience across disciplines lost	Medium

[1] ABET, Inc., 111 Market Pl., Suite 1050, Baltimore, MD 21202, (410) 347-7700, (410) 625-2238 (Fax)

Course Objectives and Content

Three projects, each involving the design of a chemical plant, were selected and students in teams of four assigned to each project by ballot. The projects were selected so as to ensure application of knowledge based on skills acquired in earlier course work; the use of engineering standards; and practice in the meeting of constraints arising from government regulations, standards, codes, physical laws, process choice, choice of process conditions, materials, equipment, economics, and time. The projects were as follow.

1. Production of Ethylene by Oxidative Dehydrogenation of Ethane
2. Process Synthesis and Design of a Fuel Processing System for Distributed Power Generation: A Proton Exchange Membrane (PEM) Fuel Cell Approach, and
3. Acetaldehyde Manufacture from Acetic Acid.

The Instructor served as mentor and consultant for the projects, while all faculty members were invited to mid-term and end of semester oral presentations to critique and grade the projects. Members of the department's Industrial Advisory Board were also invited to the end of semester oral presentations to critique and evaluate the project presentations.

Course Outcomes and Assessment: ABET CRITERION 3

The course has been designed to incorporate continuous assessment of students using homework assignments, oral presentations and written reports to evaluate competence in the following ABET 2000 criteria:

- Ability to design systems, components and processes (criteria *c*)
- Ability to function in a team (criteria *d*)
- Ability to identify and solve engineering problems (criterion *e*)
- Understanding of professional and ethical responsibility (criteria *f*)
- Proficiency in written and oral and communication skills (criterion *g*)
- Possession of the broad education necessary to understand the impact of engineering solutions in a global and societal context (criterion *h*)
- Recognition of the need for, and ability to engage in life long learning (criteria *i*)
- Possession of knowledge of contemporary issues (criterion *j*)
- Ability to use of techniques, skills, and modern engineering tools to (criteria *k*)

ABET Learning Outcomes Assessment

The breakdown of the mechanisms used for assessment of the ABET 2000 learning outcomes is given as follows.

- Literature study: Students were required to review the literature for information on the market, available technologies, safety/environment, societal impact, process route selection (addressing outcomes f, h, i and j).
- PFDs: Students were required to develop process flow diagrams, including material and energy balance of selected process after evaluating alternatives (addressing outcomes c, d, e and k).
- HS&E: Students were required to perform and health, environmental and safety reviews (addressing outcomes d, h, i and f)
- Economics: Students were required to develop cost estimates and carry out project economic evaluations (addressing outcomes h and k)

- Design: Students were required to complete chemical engineering design of major items of equipment and mechanical design of selected items of equipment and application of suitable standard (addressing outcomes c, d, e and k)
- Communication: Students deliver interim and final report and presentations (addressing outcomes c, d, e, f, g, h, i, j and k)

Design Tasks and Report

Students were required to include the following elements in their reports.

- A cover letter to the client when handing in their design report.
- An introduction section that provides information about the product, its applications and safety issues, the world market situation, and a balanced societal impact (benefits and potential problems).
- Selection of a suitable site to locate the plant. Justifications supporting site selection and completion of an environmental impact assessment, using accident or accidental spill/release scenarios.
- The complete PFD for the process. A computer drawing tool may be used but the PFD as presented in HYSYS® considered acceptable.
- A complete material balance in a spreadsheet presentation format.
- A complete energy balance, stating clearly any assumptions made. HYSYS® may be employed for the energy balance calculations where there is a justification for dong so.
- An environmental impact assessment of the project, including health risks posed by any toxic chemicals, and a safety review identifying the major hazards associated with the process and the means provided for minimizing their frequencies and/or mitigating their consequences.
- A chemical engineering design of major items of equipment justifying any assumptions made
- A detailed mechanical design of the solution for the assigned problem and its ancillary equipment, with statements identifying and justifying any assumptions made, and reference to appropriate design standards.
- An economic analysis of the process, including the following components.
    - The net cash flow in each year of the project and plant operation
    - The future worth of the project
    - The present worth at a discount rate of 15%
    - The discounted cash flow rate of return, exploring discount rates of 25%, 35% and 40% to tabulate values, but using a calculation tool such as Excel Solver® or HYSYS® for the final answer. A suitably labeled cash flow diagram should be provided, as well.
    - An estimate of the pay back time

Oral Design Presentations

Oral design presentation evaluation forms (see Exhibit 1) used for the course were modifications of rubrics for evaluating design projects reported previously, in the literature [5,6].

Exhibit 1. Form Adopted for the Evaluation of Oral Presentations

Name of Presenters:
Title of Presentation:
Date of Presentation:
Name of Examiner/Appraiser:

	1-Not Acceptable	2-Below Expectations	3-Meets Expectations	4-Exceeds Expectations
Organization (*d*)				
Objective				
Introduction of Presentation				
Preparedness of Presentation				
Design Methodology (Design Process)				
Ability to stay within time limit				
Technical Content (*c*)				
Technical content and demonstration of understanding of subject				
Quality of design/ Analysis/Construction				
Creativity and originality of design concepts				
Design within constraints				
Proper use of codes and standards in design				
Economic considerations				
Delivery (*d*)				
Use of vocabulary appropriate to technical subject and audience, clarity and confidence				
Attire, posture and eye contact				
Efforts of all group members/Group dynamics				
Visual Aids (*d*)				
Quality and adequacy of visuals				
Readability and Relevance of Slides				

Implementation: Feedback, challenges and opportunities

The transition to the discipline-focused capstone senior design has been characterized by challenges and opportunities for both students and instructors. The need to evaluate student performance using the ABET 2000 learning outcomes a through k, meant carefully assigned mini tasks to students, and the subsequent grading of the resulting deliverables by the instructor. The students found the change helpful and challenging but stressful since their grades were tied closely to their ability to demonstrate skills in the ABET *a* through *k* criteria.

At the start of the second year of implementation, students beginning the capstone course were more comfortable about the workload and the demand on their time, since they were expecting it based on what they had heard about the course changes. The following steps have been taken to make this possible:

1. Increased emphasis on the importance of the capstone course by faculty in communications with students throughout the curriculum, raising student awareness of expectations;
2. Use of homework assignments that provide hands-on use of HYSYS® for material and energy balance calculations;
3. Class lecture sections on effective literature review and other outcomes related topics; and
4. Handouts providing copies of papers from the literature describing procedures and techniques used by chemical engineers in designing chemical plants [7-9].

References

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