
AC 2012-4833: A COURSEWORK PLAN FOR IMPROVING SKILLS NECESSARY FOR SUCCESSFUL CAPSTONE PROJECTS

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A Coursework plan for improving skills necessary for successful capstone projects

Abstract

One of the main courses that students do in an undergraduate engineering program is the capstone design project. Capstone projects are intensive learning projects which require a lot of research, project management, and technical communication skills to succeed in the course. There are a lot of skills that need to be developed for a successful capstone project. Capstone projects and the accompanying final report show the quality of student work thereby reflecting a quality program. Capstone projects are also valued highly in the accreditation process. The Accreditation Board for Engineering and Technology (ABET), which provides accreditation to engineering programs in US have different criteria to evaluate a program. There are many general criteria and some specific criteria applied to the program. The general criteria are related to programs, educational objectives, continuous improvement process, program outcomes, curriculum, faculty, facilities, and support. Program outcomes are more specific, since the ABET report would show the curricula, course work, and other documentation to show the effectiveness of the program. Program outcomes are criteria 3 of the ABET criteria. One of the main ABET outcomes is to have engineering students communicate effectively. Being a brilliant and creative engineer is just not enough, in today's global world engineers need be able to work and communicate in diverse teams and should be able to influence and engage coworkers in discussions and negotiations. Writing technical information appropriately to communicate with others is essential and needs to be developed in technical subjects with students who study engineering. In this paper authors will describe and consider the course work plan for a successful capstone project taught at the Petroleum Institute, Abu Dhabi.

Introduction

Capstone design has become an integral component of the undergraduate engineering program; capstone design is showcase product for senior engineering students and also a mandatory course according to ABET^{4,5}. During the capstone design experience, the senior students utilize the knowledge gained from their freshmen year courses to apply towards their senior project. There is a firm emphasis on their technical communication skills also such as technical writing, technical drawing, and communication proficiency. Teaching effective technical communication is challenging since most of the students are non-native English speakers and where teaching English itself is a hurdle. This paper will discuss the course work plan in improving the skills that is necessary for a successful capstone project. There are two levels of communication courses that students have to go through in their freshman year, followed by the two engineering design courses (STEPS: Strategies for team based engineering problem solving) for getting the students prepared for the capstone design course. The goal of the communication faculty and engineering design faculty is to have the students develop skills in both technical design and writing, in effective communication and to provide students with enough opportunities to refine these skills developed in their freshmen year.

Educational settings tend to provide highly specialized contexts for learning, and when there is change in demographics, culture, or learning styles it can become more complex. Most of the universities in the US are multidisciplinary, which present challenges often not considered in the technical communication curriculum³. Technical communication programs are addressing this issue by building partnerships with programs in mechanical engineering and industrial engineering as has been discussed by Wojahn, et al. (2). In this paper the authors describe and examine the technical and professional communication competency strategies taught at the Petroleum Institute (PI) of Abu Dhabi in the United Arab Emirates to help prepare freshman and sophomore engineering students for their senior level college courses (in a middle east university). The PI has an English medium curriculum and for a majority of its students English is a second or foreign language. A description of the communication courses that students experience in the first year will be presented, followed by the sophomore engineering design courses and preparing students for the capstone design course. The goal of the communication and engineering design faculty is to have the students develop effective communication skills in both technical writing and design, and to provide students with opportunities to refine these skills. We will also discuss technical communication activities and strategies that are used in the courses, assessing the same, and a feedback mechanism to improve effectiveness. As a result of the various strategies used at The Petroleum Institute, the quality of writing in the final senior design projects has improved significantly.

Background

The mission of the Petroleum Institute is to impart world-class education in engineering and applied sciences in order to support and advance the petroleum and energy industries. The Institute strives to develop students as whole persons and as the future leaders in their respective fields of expertise in the UAE and globally. One of the goals to achieve in a graduating student is that he/she will appreciate the critical role played by verbal, written and graphical communications in engineering practice and project management, and will have the corresponding skills to communicate with a range of audiences, and to employ information technologies where appropriate.

Curriculum at The Petroleum Institute

The PI was created in 2001 with the goal of establishing itself as an international institution in tertiary engineering education and research in areas of significance to the oil and gas and the broader energy industries. Currently the PI offers Bachelor degrees in Chemical, Electrical, Mechanical and Petroleum Engineering, and Petroleum Geosciences. The students after they go through high school are admitted to PI based on their TOEFL score and the GPA in high school. Most of the students go through a foundation program before they are enrolled as a freshmen student. The foundation program is designed to help students develop knowledge, study skills, technical, analytical, and communication skills which are necessary to meet the PI's entrance requirements and assist them in their future studies at the Petroleum Institute. The foundation program at the PI is called as the Advanced University Placement program.

Program framework

Once the student reaches the freshmen level there are core courses that have to be completed irrespective of their majors. The core courses are offered through the Arts and Science Program and some elective courses required for the engineering programs are also offered through Arts and Science. The six departments within the Arts and Science department include Mathematics, Physics, Chemistry, Humanities and Social Sciences, Communication, and General Studies (See Figure 1). Students must take these required courses in a sequence.

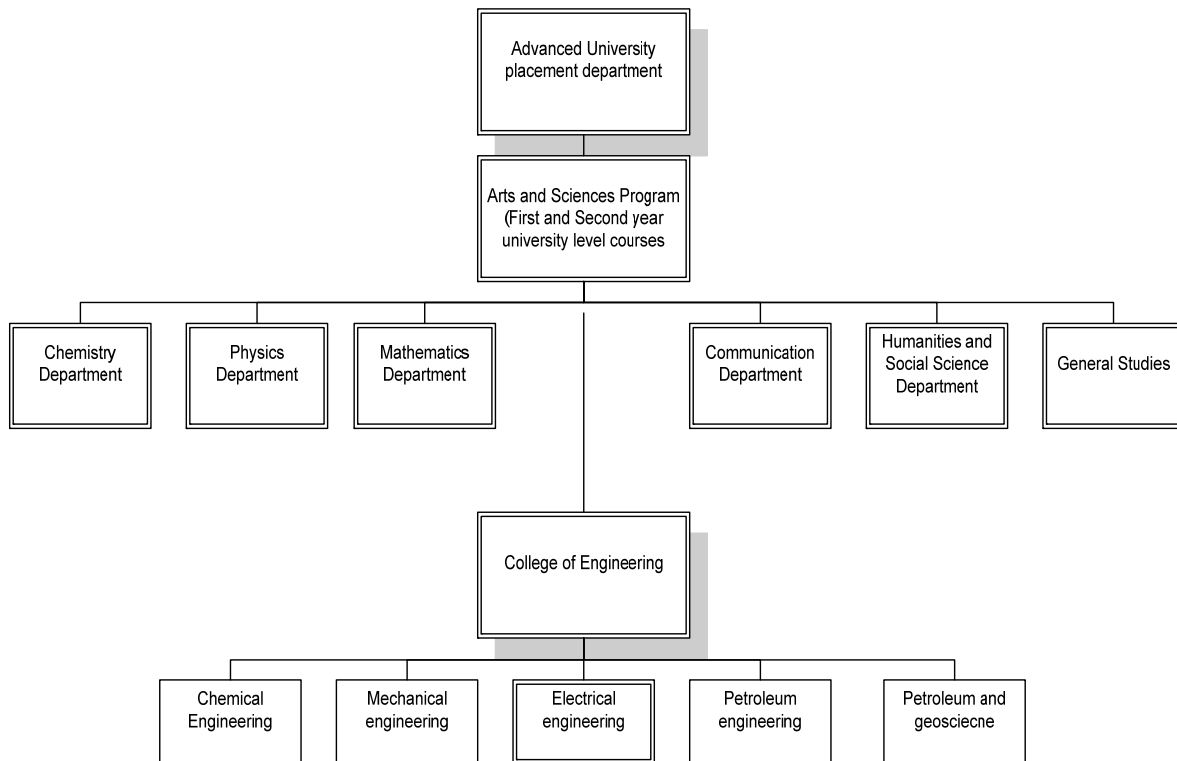


Figure 1. The Petroleum Institute Academic Department Structure

Coursework plan and sequence overview for improving skills

The general studies department offers a sequence of two freshmen design courses called STEPS, which stands for Strategies for Team-based Engineering Problem Solving. In STEPS courses students integrate what they are learning in science, mathematics and communications, couple it with teamwork and project management tools and build a working prototype of a useful machine. The requirement to start the STEPS courses is that they should complete the first course of Physics and two levels of communication class. The framework of the communication and STEPS core course are shown in Figure 2. After successful completion of the courses in Arts & Sciences, students enter one of the six engineering departments to do upper level courses and pursue a specialized engineering degree program.

As stated earlier, one of the educational goals of the PI is that graduating students will be professionally competent in oral, written, and professional engineering communication skills.

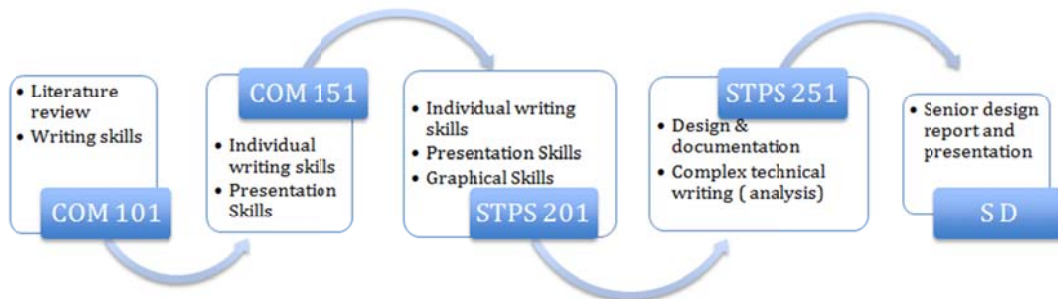


Figure 2: Framework for technical communication development

Where:

STPS 201 - First course in engineering design

STPS 251 - Second course in engineering design

SD – Senior design / Capstone design course series

The two freshmen communication courses that are built into the curriculum have a variety of strategies to develop and improve professional and technical communication skills. In the first course (COM 101) students investigate and design their own research study on topics relevant to their university and academic context. This is done in teams so that they need to use negotiation and collaboration skills in order to successfully complete the research project. They also examine case studies on relevant current events and educational topics. The results are useful to the students and the institute as they learn more about themselves and their own educational environment while developing their communication skills.

The PI first year communication courses are designed to meet the needs of engineers who are required to be effective and successful professionals. One of the pedagogical objectives is to produce articulate and autonomous learners who are able to use sophisticated thinking and communication skills. The communication department's approach is based on the belief that learners will best develop these skills through the acquisition and articulation of knowledge. Therefore the communication courses focus on problem solving and collaborative learning in order to develop technical communication skills connected with:

- Oral and written communication
- Academic, scientific and technical observations
- Qualitative and quantitative analysis
- Professional interaction competencies
- Critical thinking

The second freshman communication course (COM 151) builds on skills learned in the 101 course. Students carry out a semester-long academic, educational or technical project that should be useful to themselves and/or the PI. Technical communication “skills are developed as students participate in seminars and work in teams to gather and share information, leading to extensive, full written reports and multimedia oral research presentations” (1). The planning, negotiation and collaboration that develops during the teamwork and research activities are critical strategies set up to facilitate the improvement of student professional and technical communication skills.

Continual assessment of these skills and competencies is done through a variety of methods, including:

- Weekly individual writing assignments
- Team source review descriptions (both written and oral)
- Team planning meeting minutes (written)
- Written and oral progress reports
- Recommendation report draft revisions (written)
- Final recommendation report (written)
- Oral Presentations

Strategies for Team Based Engineering Problem Solving Program is PI’s freshmen engineering program. There are two levels of STEPS (STPS 201, STPS 251) courses, in the first level of the STEPS course is more real life problems and in the second level of the course is more of a theoretical approach with computer simulation and analysis. The second level design course is more departmental specific. Both are core courses to be taken in succession.

The overall aim of the STEPS program is to introduce and expose students to the engineering design process and integrate a range of skills and competencies that will simulate project management and real-world design activities in a professional engineering environment. This program requires teams of students to respond to client specifications by designing, managing and presenting technically feasible solutions to real-world problems. The program aims to facilitate good engineering practices with a strong focus on behavioral competencies and communication skills. Teamwork, organization, planning, research skills, and problem solving are essential for success. All students are actively engaged in teamwork and solving open-ended problems using methodical approaches and state- of-the-art design and communications tools.

During the semester, students also regularly present the results of their project work using oral, written and graphical communication skills. The progress and development of each team project and each student's contribution is closely monitored and evaluated by qualified engineering design experts and qualified English communication specialists for the purpose of providing helpful feedback and advice to improve project work, communication skills and presentation skills.

In addition to the skills improved from the communication courses, the students in the STEPS courses improve their skills in problem solving. Engineering has brought a lot of

improvement and changes in society, the central most important is the problem solving and problem analysis, that in the physical environment is forcing the formulation of problems and interactive designs of solutions to the center of professional activity, and most of these activities are done by some mechanism of technical communication.

The Design Courses starting with the STEPS courses are supervised by two professors, who act as faculty mentors for the student. One faculty would be an engineering faculty who assists in engineering related questions and other faculty is from the communication department who would assist students in writing proposals, and also for presentation. The student teams are usually formed of 4 or 5 members, depending on the size of the class. All students are given a personality typing evaluation to use as input in the team selection process. The students are also given another form to fill in their personal details relevant to the university course work which have information related to the courses attempted, credits, work experience, GPA, skills. All this information helps the faculty divide the students into equally skilled teams. One of the areas that faculty point out in the class is the team work.

The process facilitating strategy skills by means of technical communication is also improved through the STEPS courses, some of the tools and strategies used are listed below:

- Knowledge of tools and strategies for project management – communicating to the various team members using MS projects to assign resources, and track the progress of the student project
- Graphical Communication – recorded communication by means of engineering drawing, engineering sketches to discuss ideas for the designs
- Students to work as professional teams and record of all the meeting minutes which is also a means of improving technical communication.

The assessment of these skills and competencies are done through a variety of methods, including:

- Weekly journal assignments (written technical communication skills)
- Literature review (written technical communication skills)
- Team planning meeting minutes (written)
- Conceptual design report (written technical communication skills and graphical communication which includes sketches and computer generated models)
- Recommendation report draft revisions (written)
- Final report (written)
- Oral Presentations (Midterm review presentation , final presentation)
- Poster presentation (Oral communication, graphical communication)

Evidence of the success of this approach and the courses described above is in the faculty assessment that the qualities of writing in the final senior design projects have improved significantly during the period of time that these techniques and strategies have been employed in the program.

The course layout from the communication classes and the STEPS courses provide students with enough skills to be successful for their capstone design experience. The capstone design is a core course for all the engineering students with an opportunity to solve to real world problems. The capstone design course is also an ABET requirement for the engineering programs and also serves as a bridge between the engineering curriculum and the engineering profession. The capstone design course at The Petroleum Institute involves generating a final report, which contains evidence of research, methodology, a decision matrix in selecting design, substantial analysis, and the synthesizing of the selected design.

Conclusion

This paper has illustrated the course work plan for improving the skills necessary for a successful capstone project at the Petroleum Institute, UAE. It is crucial that engineering students be proficient in verbal, written and graphical communications competencies and have the corresponding skills to communicate with a range of audiences, colleagues and stakeholders. The main pedagogical objective of the capstone project is to instill these abilities and competencies to prepare students for their upper level engineering specializations. The capstone project workplan employs a variety of strategies and tools to provide students with a range of opportunities to expand and improve the skills necessary to become successful engineers in the future.

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