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Developing a professional skills matrix for engineering students

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ABSTRACT

Graduates of engineering programs in today's globalized economy must be able to apply their technical knowledge in team-based environments where flexibility, communication, and cooperation are needed to solve problems that do not necessarily have well-defined technical boundaries. Despite the importance of soft skills, research indicates that students in engineering programs are not satisfied with the soft skills training they receive at the university level. In order to better integrate soft skills and technical knowledge in the university curriculum, the mode of instruction must veer away from traditional lecture-based models to more student-centered and project-based approaches.

At the Petroleum Institute (PI), an engineering university in Abu Dhabi, the identification of core professional skills is an ongoing process that involves the integration of technical knowledge with soft skills training to prepare graduates for work in the oil and gas industry. These skills include communication (oral, written, and graphical), teamwork, project management, critical thinking, and lifelong learning. Given the interdisciplinary and global nature of the industry, these skills are essential for engineers to be successful in the field.

This paper discusses the process of mapping the engineering professional skills across three curriculum levels in the Arts and Sciences Program at the PI. It also includes feedback from students who completed the target courses to show how they perceive the growth of their own professional skills as engineering students and their level of preparedness for work in the oil and gas industry.

Keywords: Soft skills, professional skills for engineers, curriculum development

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INTRODUCTION

Globalization and the changing work environment have prompted the need for engineers to possess soft skills as well as technical knowledge.[1] Numerous studies have addressed the importance of soft skills development for new engineering graduates.[2–6] In a study sponsored by British Petroleum,[7] for example, 'ability to learn', 'teamwork' and 'communication' were noted as the most important skills for engineers in the oil and gas industry to have in order to be successful. Technical skills, knowledge and analytical skills were considered less important than these soft skill areas. Despite these perceptions, respondents felt that they were not being adequately prepared by universities to improve these soft skills.

In addition to the lack of adequate professional skills, one of the challenges that new engineers face is the increasing interdisciplinary nature of the field. It is no longer sufficient to have knowledge of one's own area of specialization in engineering. Instead, new graduates will be working in multidisciplinary teams that require cooperation in order to tackle problems that do not necessarily have distinct technical boundaries.[8] Many employers have expressed dissatisfaction with the soft skills of new graduates that they have hired,[9–11] indicating that problems in engineering projects were mainly due to poor interpersonal skills, rather than a lack of technical knowledge. Soft skills that have been identified by employers and researchers as needing additional training include communication (oral and written), project management, problem solving, lifelong learning and teamwork.[12–13]

BACKGROUND

The present curriculum alignment project was undertaken at the Petroleum Institute (PI), an engineering university in Abu Dhabi that focuses on the development of graduates who can meet the needs of the oil and gas industry in the United Arab Emirates, as well as contribute to alternative energy solutions in the region. The student population at the PI is predominantly Emirati and there are two campuses – one for male students and one for female students. The PI offers Bachelor and Master degrees in a number of engineering disciplines, including Chemical, Electrical, Mechanical and Petroleum Engineering, as well as Petroleum Geosciences. Many undergraduate students attend a foundations program to gain the prerequisite skills in English and Math to prepare them for Freshman level courses. In their Freshman year, students are placed into cohorts as part of the Freshman Year Experience (FYE) and registered for core courses that are irrespective of their designated major. These courses are offered through the Arts & Sciences program and include prerequisite work that emphasizes the professional skills and technical knowledge needed for success in future courses as well as in the industry.

PROFESSIONAL SKILLS AT THE PETROLEUM INSTITUTE

The identification of core professional skills, or soft skills, is an ongoing process at the PI. In order to better facilitate learning within the core courses that most closely address professional skills, the current project was undertaken to identify the activities and assessments used in those courses as well as align those skills across the curriculum.

The Freshman Success Seminar (ENGR101) is an introductory course that emphasizes the development of professional skills through lectures and activities focusing on the role of engineers in the petroleum industry. Students are provided information about the different majors offered at the PI to help them make an informed decision. Field trips, guest lectures, and hands-on projects introduce students to technical terminology and practices, and provide opportunities for students to become familiar with the prerequisite soft skill areas.

The Communication Department offers two courses (COMM101 and COMM151) that help students to become better communicators using the English language. COMM101 is a course that is taken in conjunction with ENGR101 and focuses on introducing students to the language skills that are needed for academic success at the PI and beyond. Critical reading, writing and presentation skills are taught through a humanities framework to allow students to engage in topics that go beyond the engineering industry. This provides students with a broader knowledge base that complements the engineering topics that are the focus of ENGR101. The upper level Communications course (COMM151), then, builds on the language skills introduced in COMM101 and allows students to become more independent learners through longer, more intensive team-based activities and research projects.

Strategies for Team-Based Engineering Problem Solving (STEPS201) is an engineering design course that integrates technical knowledge with soft skills training. Students learn the process of engineering

design by working in teams to develop conceptual designs that solve real world engineering problems. Instructors facilitate the course by taking on the role of clients and advisors in the design process. This allows students to be in the driver's seat, thus providing them the opportunity to experience project management and interdisciplinary teamwork. Regular team meetings with the instructors are scheduled throughout the semester; written and oral reports are based on this facilitation model. Graphical communication is also introduced in the STEPS course as students are given instruction in the use of Solidworks software for computer-aided design.

RESEARCH QUESTIONS

The following research questions provided the framework for the current study:

1. What professional skills do students at the PI need in order to be successful engineering graduates?
2. How are these skills addressed in the core identified courses?
3. What activities and assessments are used to develop and evaluate competency in the professional skills?
4. What are students' perceptions of their professional skills after completing the target courses?

METHODS

The current alignment project was based on information gathered from a cohort of ten Communications and Engineering faculty at the PI. The identification of professional skills was primarily based on the extant literature. Faculty that taught the identified core courses were asked to provide information regarding the level of each professional skill as it was applied in their particular course(s). The skill levels ranged from 1 (Novice) to 4 (Mastery). Faculty members were also asked to describe the activities and assessments used to develop and evaluate the professional skills in their courses. The Principal Investigator was then charged with collating and organizing the information into a Professional Skills Matrix. The Principal Investigator also surveyed students who had completed the four target courses to determine their perceptions regarding the growth of their professional skills.

RESULTS

A. Mapping the professional skills across the curriculum

Based on the extant literature, the following professional skills were identified: communication (oral, written, and graphical), teamwork, project management, critical thinking, and lifelong learning. The skills were further defined to enable a shared understanding of each concept. The descriptors for each professional skill are shown in Table 1 below:

Table 1. Professional skills and descriptors.

Professional Skills	Descriptors
Written Communication	• Generate research questions, identify relevant literature, extracting relevant information, integrating information in written documents, acknowledging sources, in-text citations • Develop a knowledge of genre
Oral Communication	• Present information and interact clearly and logically; delivered at a level of detail appropriate for the intended audience
Graphical Communication	• Present information in clear graphical forms appropriate for the task (Excel graphs and charts) • Engineering software • Sketching and visualization
Teamwork	• Demonstrate skills in effective teamwork • Be able to resolve conflicts, delegate duties fairly, achieve goals, communicate regularly with team members
Project Management	• Identify project tasks required to achieve goals • Manage time, manpower and resources to complete tasks
Critical Thinking	• Ability to participate in creative thinking and critical analysis and evaluation of information to generate alternative feasible solutions and making informed decisions
Lifelong learning	• Demonstrate ability and desire to continue learning beyond the required scope of the course

Faculty members teaching ENGR101, COMM101, COMM151, and STEPS201 provided information regarding their courses based on the framework shown in Table 1. In the introductory courses

(ENGR101 and COMM101), the professionals skills were either at the beginner level (Level 1) or not introduced in that course. This is consistent with the introductory nature of these two courses. The following skills were addressed in both courses: written and oral communication, teamwork, project management, critical thinking, and lifelong learning. COMM101 also expected students to use charts and graphs to illustrate data distribution. Technical software and sketching/visualization were not addressed in either course. A variety of activities, lectures, and assessments were used to check on the progress of the professional skills. Most commonly used were research assignments (Written Communication, Critical Thinking), team and individual presentations (Oral Communication, Graphical Communication, Teamwork), project timelines and calendars (Project Management), and reflection activities (Lifelong Learning).

In COMM151, the skill level of activities was generally identified as beginning to intermediate (Level 1–2). This applied to all the identified skills, except for graphical communication-engineering software, which was not introduced in the course. COMM151 utilized similar activities as the previous courses to build upon existing skills, but with greater emphasis on teamwork and project management. Instead of a variety of small research projects, COMM151 introduced students to a semester-long project that required more team collaboration and time management.

In STEPS201, the skill level of activities was generally in the range of intermediate to advanced (Level 2–3), except for engineering graphics which was at an introductory level. In this course, students applied their teamwork skills for two long-term projects focusing on engineering design. Students were responsible for maintaining professional communication with professors through weekly team meetings using a variety of project management tools, such as Gantt Charts, Linear Responsibility Charts, and Project Completion Matrices. As a project-based course, STEPS201 limited the use of lectures to the first four weeks wherein the engineering design terminology was introduced. After that, the course became primarily student-led and project-centered. In this course, students were provided instruction in Solidworks, a computer-aided design (CAD) software which enabled them to develop professional graphics to support their designs.

B. Student perceptions of their professional skills development

Students in two Senior Design courses were asked to reflect on their professional skills development at the PI. A total of 51 students completed the survey (36 male, 15 female). Results suggested that a majority of students felt adequately or highly prepared for all soft skill areas except graphical communication/CAD (Table 2).

Table 2. Student perceptions of preparedness in professional skills.

Professional Skill	Preparedness
Written Communication	82.4% adequately or highly prepared
Oral Communication (Presentations)	78.4% adequately or highly prepared
Graphical Communication (Tables/Charts)	80.4% adequately or highly prepared
Graphical Communication (CAD)	45.1% adequately or highly prepared
Teamwork	96% adequately or highly prepared
Project Management	77.5% adequately or highly prepared
Critical Thinking	72.9% adequately or highly prepared

To address lifelong learning, students were also asked to reflect on their experiences as an engineering student at the PI and identify the improvements they had seen and the strategies they had used. Of those responding, the majority perceived improvements in communication skills (58%). Improvements in time management, problem solving, and teamwork were also noted, but to a lesser extent. Students attributed improvements in soft skills to persistence, practice, and an increased sense of responsibility and maturity.

DISCUSSION

Research indicates that teaching soft skills can be a challenging task. Balancing content teaching with soft-skills training can be difficult for instructors and students alike. Focusing on integrating technical skills and soft skills in the classroom involves a change in the traditional learning environment that may include balancing the time spent on both areas, developing curriculum that incorporates both aspects and addressing interpersonal team issues.[14] Using project-based learning, facilitation rather

than lectures, and providing simulations of real world experiences are some ways of improving professional skills.[15] Activities that employ these teaching techniques are currently being used in the target courses at the PI. For example, students take ENGR 101 and COMM 101 simultaneously. In these courses, students are introduced to teamwork through group activities and team assignments. Students are able to experience revolving teams, where group membership changes throughout the semester, as well as non-revolving teams, where group membership is set once and remains the same for the remainder of the course. STEPS builds upon the skills that are introduced in prerequisite courses by integrating teamwork, communication, and project management through the simulation of real world engineering design problems. Thus, students are provided numerous opportunities to get experience working in multidisciplinary teams. Students are also expected to produce a variety of written reports and oral presentations, both individual and team-based.

Research skills are addressed in different ways from one course to another. Although research is primary assessed through written reports and presentations, the motivation for conducting research is different in each course. In ENGR101, for example, research is conducted on the engineering majors offered at the PI in order to help students better determine their major course of study. The COMM courses, on the other hand, focus on social science research. This is done to help students obtain a broader liberal arts education and to connect engineering to other professional disciplines. In the STEPS course, research is directly linked to the engineering design projects that students are completing. Students in STEPS need to apply the information from primary and secondary sources to the development of their conceptual designs. Thus, the purpose of research varies from one course to the next, allowing students the opportunity to discern the myriad of ways in which research is important in academia and within the engineering field.

The present curriculum alignment project was undertaken to provide students, faculty, and administrators with a tool to quickly ascertain the level of instruction for each of the professional skill areas, the activities that are currently being used to address those skills, and the deliverables associated with each of them. In terms of skill level across the courses, the focus was not so much on the skill level of the students in each course, but rather the level of the material as it is presented in each course (introductory/beginner, intermediate, or advanced). Although a variety of tools and teaching methods are being used by the core courses, the lack of a shared curriculum framework made it difficult for faculty to know exactly what students had been learning across the levels. This led to confusion regarding the skills that students should bring from one course to another. One goal of the Professional Development Matrix was to allow faculty and administrators to clearly see the progression of curriculum for the identified soft skills. Curriculum materials and assessments within one course could then be readily updated and evaluated within the framework of the other core courses.

The Matrix also clearly identifies areas that may need improvement. For example, in the current curriculum, engineering software and visualization practice is clearly lacking. Students are not introduced to these skills until the STEPS course. Graphical communication up to the STEPS course is mainly concerned with developing tables and charts using Excel software to represent numerical data for written and oral reports. As the use of engineering software does not really fit with the learning objectives of the existing introductory courses, a separate course that focuses on engineering software and sketching may be useful to help students develop visualization skills prior to enrolling in STEPS.

Survey responses regarding students' perceptions of their professional skills support this notion. Students felt adequately or highly prepared in all soft skill areas except graphical communication (CAD). Despite this perception, in discussing lifelong learning, students predominantly noted skill development in written and oral communication, with some mention of improvements in teamwork, project management and problem solving. Although students attributed the growth of these skill areas to their own efforts, rather than to any course materials or instructional activities, responses to this item suggest that more needs to be done to ensure that professional skills are adequately being addressed at the university. Proposed improvements included additional coursework in CAD and continuous instruction in engineering design. Currently, after completing STEP 201, students enroll in STEPS 251, which is a design course run by the individual engineering departments. Then there is a gap in their Junior year, after which students are required to complete a Senior Design course. Students suggested that more continuity in the curriculum regarding engineering design would help them better apply their technical knowledge in Senior Design and help them maintain their professional skills.

CONCLUSION

A shared framework for addressing professional skills should be an essential component of every engineering program. The extant literature indicates that soft skill development is the area where engineering graduates need more support. A Professional Skills Matrix can identify the aspects of soft skills training where programs are doing well, as well as highlight those areas that need more emphasis. Continuous improvement of engineering programs requires buy-in from all stakeholders. Thus, it is important to gather feedback from instructors, students, and employers when constructing a framework for the development of professional skills. By developing a shared understanding of the skill levels, activities and assessments for developing professional skills, engineering programs can better ascertain how well they are preparing students for the industry.

REFERENCES

[1] Kumar S, Hsiao JK. Engineers learn 'soft skills the hard way. *Planting a seed of leadership in engineering classes. Leadership and Management in Engineering*. 2007;7(1):18–23.
[2] Chapman GM, Martin J. Developing business awareness and team skills: The use of a computerized business game. *Journal of Engineering Education*. 1996;85(1):103–106.
[3] Clagett CA. Workforce skills needed by today's employers. *Market analysis MA98-5*. Largo, MD: Prince George's Community College; 1997.
[4] Goldberg DE. Change in Engineering education: One myth, two scenarios, and three foci. *Journal of Engineering Education*. 1996;85(4):107–116.
[5] Klukken PG, Parsons, JR, Columbus PJ. The creative experience in Engineering practice: Implications for Engineering education. *Journal of Engineering Education*. 1997;8(4):133–138.
[6] NSPE. Engineering education issues: Report on surveys of opinions of Engineering deans and employers of Engineering graduates on the first professional degree. *NSPE Publication No. 3059*. 1992.
[7] SPE Research, Training and Development Survey. *SPE International*. 2012.
[8] Rugarcia A, Felder RM, Woods, DR, Stice JE. The future of engineering education I. A vision for a new century. *Chemical Engineering Education*. 2000;34(1):16–25.
[9] Alpern M. Critical workplace competencies: Essential? Generic? Core? Employability? Non-Technical? What's in a name? *Canadian Vocational Journal*. 1997;32(4):6–16.
[10] Shtub A. *Project management: Engineering, technology, and implementation*. Engle Cliffs, N.J: Prentice Hall; 1994.
[11] Tan A L. *Property development in Malaysia*. Kuala Lumpur: Synergy Book International; 1998.
[12] Woods DR, Felder RM, Rugarcia A, Stice JE. The future of engineering education III: Developing critical skills. *Chemical Engineering Education*. 2000;34(2):108–117.
[13] Tong L F. Identifying essential learning skills in students' engineering education. 2003, Proceedings of HERDSA.
[14] Dannels DP, Anson CM, Bullard L, Peretti S. Challenges in learning communication skills in chemical engineering. *Communication Education*. 2003;52(1):50–56.
[15] Pulko SH, Parikh S. Teaching 'soft'skills to engineers. *International Journal of Electrical Engineering Education*. 2003;40(4):243–254.