# Challenges to Developing Professional Skills in Undergraduate Chemical Engineers at a Minority Serving University

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## Abstract

Undergraduate engineering students at a minority serving institution present unique challenges for professional skill development. Students in the Chemical Process Design II and III course sequence in chemical engineering at Texas A&M University-Kingsville are introduced repeatedly to the importance of communication skills, and the topics of professional engineering licensure and life-long learning. A fraction of these students have English as their second language, and development of oral and written communication skills to the level of fluency expected of engineers in the United States is challenging. The students are tested in their oral communication skills through delivery of six group-format project presentations in the two course sequence. The course sequence also requires significant written communication exercises, particularly in the second course which is a writing intensive course. The overall performance of those students with English as a second language is reasonably strong once the instructor's grading expectations are realized and the students avail themselves of outside assistance, such as provided by the University Writing Center. The undergraduate student's development of a sense of the importance of life-long learning is also challenging for the instructor to instill. An open-ended technical problem requiring solution as part of a senior design project is an opportunity for the instructor to use coaching methods to guide students to their own independent solution, thus reinforcing self-learning outside of the instructor-led paradigm. Instilling an interest for professional registration is also difficult to accomplish, in particular because the fraction of chemical engineers that become registered in their career is far less than in other engineering disciplines such as civil engineering. The approaches used to accomplish instruction of these important professional skills at a minority-serving institution are presented.

## 1. Introduction

Communication skills, recognition of the need for life-long learning, and awareness of professional registration are non-technical professional skills that engineers graduating with a bachelor's degree should be equipped with upon embarking upon a professional career in industry. At Texas A&M University-Kingsville (TAMUK), discussion and assessment for these skills is woven in with technical instruction in the two-course senior design sequence, known as Process Design II / Process Design III. The author has served as the primary instructor for these two courses for the last 2½ years. This paper presents the instructor's approach to improving student performance in these areas.

The students in the senior design course sequence present challenges in these areas because of (a) language barrier (English is not their primary language) for some students; (b) unfamiliarity with professional working environment and culture; and (c) student maturity and experience. The assessment of student performance in each of these skill areas described herein are related back to these challenges.

## 2. Communication Skills

### 2.1 Course Instruction

The instructor emphasizes the importance of learning and practicing good communication skills throughout both of the courses in the senior design experience, and draws upon his 25 years of consulting engineering experience for pertinent examples. Apparently the most common obstacle to effective communication, both oral and written, is the language barrier for those students whose first language is not English. All students observed in three senior design class sequences to date have been able to speak and write basic English. However, those foreign nationals whose primary and secondary education was not in English typically have the greatest challenge in producing passing scores in the communication aspects of the design course sequence. The second most common obstacle to good communication is a lack of self-

confidence or nervousness amongst a minority of students in the oral presentations. Also, many students relay that they have very little public speaking experience, even though they are college seniors and most of them have already completed a required business communications course prior to the senior design course sequence.

In the Design II course, the students are required to work on four short group projects on different topics. In the first and last projects in this first course, the students submit a written report and give a short 4 to 5 minute presentation. In the second and third projects, only a written report is submitted. The instructor grades the report on a group basis, while the students receive individual grades for the oral presentations. Constructive feedback is provided on the written reports in the form of embedded comments in a Word document, which the students use to guide their preparation of a final report version, which is also graded. Constructive feedback is provided on the oral presentations as verbal comments to the entire class on poor speaking habits observed among many students, as well as individual comments for specific students. In the case of individual students, the most common issue are those students who are simply very nervous speaking in front of a group of peers, or those students who absolutely require notes to assist in completing a short speech. In the Design III course, further development of oral and written communication skills is emphasized. This course is a Southern Association of Colleges and Schools (SACS)-designated writing-intensive course (5,000 word requirement for each student during the semester). The requirement is met with the instructor's assignment of ten 500-word student essays, one per week, over the course of the semester. The prompts for this series of student essays cover a range of topics germane to engineers about to graduate, such as process safety, engineering registration, ethics, and project management. The oral communication skills are also emphasized in that the students continue to present longer and longer group presentations on the progression of their senior design projects.

**2.2 Student Evaluation**

The instructor's expectation for student communication skills is to witness a steady improvement in this area as the Design II / Design III course sequence progresses. Steady improvement is expected because the students have multiple opportunities to practice and improve on these skills through the course sequence. The data presented here on communication looks at student scores from this perspective.

The ten writing assignments used in the Design III course to evaluate written communication skills of each individual are spread out evenly over the first 11 weeks of a long semester. Figure 1 presents the trend in the average of student scores for each of the ten assignments. In each assignment, 60 percent of the grade is based upon proper

and effective written communication. As the graph indicates, improvement in the assignment scores (positive slope of linear estimate) occurred for the spring 2017 and summer 2017 courses, but not for the spring 2016 course. The lack of improvement with time in the first course may be attributable to this being the instructor's first experience in grading papers of this type. The improvement in scores in the other two Design III course offerings indicates the grading emphasis on communication skills is having the desired effect. One component of the writing intensive assignments is the requirement that the instructor provide feedback on at least one of the assignments, which the students must then respond to in the form of a second version of the document used for final grading.

The improvement in students' oral communication skills were assessed as the change between two sequential events, that is a first versus last presentation score (scores all individually-based). The data presented here is a simple assessment of whether or not there was an improvement in oral presentation scores between the two chosen occurrences. The instructor's oral presentation grading rubric includes 60 percent of the grade being based upon proper and effective oral communication. Additionally, the comparison presented here is based only on those students who had a score below 90 on their first presentation. The instructor believes his scoring rubric is such that a score of 90 or above represents a student with reasonably good all-around presentation skills whose score will mostly be a function of the technical information he or she presents.

Figure 2 presents these results of the number of students that displayed an improvement from a first oral present-ation to a final oral presentation. Approximately 80% of students showed improvement in their oral presentations in the first two data sets, while only 20% showed improvement in the third. The data for spring 2016 Design III course had one intervening oral presentation between the first and last used for comparison. The data for spring-summer 2017 Design III course had three intervening oral presentations between the first and last used for comparison. The data for fall 2017 Design II course had no intervening oral presentations between the first and last used for comparison. This lack of intervening presentations is the likely reason that the improvement numbers were much lower than in the first two data sets.

Potential language barrier and student maturity and experience level are the challenges that are most relevant to whether students are successful in this skill area. Practice through repetition of both written and oral communication activities is a primary pathway to improvement. This approach also ties in with student maturity and experience.

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## 3. Life-long Learning Skill

### 3.1 Course Instruction

The "recognition of the need for, and an ability to engage in life-long learning" is ABET (Accreditation Board for Engineering and Technology) student outcome "i". In chemical engineering at TAMUK, this student outcome is assessed in the Design II class, but not the Design III class. Life-long learning is an important issue for undergraduate seniors to embrace as they are about to embark on a professional career. The instructor has found two ways to assess student comprehension and acceptance of this idea. First, the instructor looks for instances during student group performance of their senior design projects where individuals or the entire group struggle to find a tractable approach to a particular technical problem for which they have not received formal instruction in prior chemical engineering core coursework. A good indication of embracing life-long learning is when the students are able to delve into the technical material to the point necessary to generate a reasonable solution to their technical problem in their senior design project. The second way that the instructor has found to assess student acceptance of life-long learning is the creation of a homework problem set that tests the student's understanding of a quantitative topic on which they have not yet received a lecture, but for which instructional information is readily available (such as in the course textbook) to the students. The instructor is beginning to implement this latter approach in the Design II and Design III course sequence.

### 3.2 Student Evaluation

In two years of Design III course instruction, the instructor has observed roughly one-half of the senior design groups (7 out of 13 in spring 2016, 5 out of 11 in spring 2017) demonstrate life-long learning acceptance, as indicated by the numbers shown in Figure 3. In most cases, the independent search for solutions or approaches for a particular technical issue facing a design project group begins with the work of a single member of the group. Sometimes this effort spreads to all the group members, although sometimes it does not. A much lower incidence of life-long learning occurred in the summer 2017 Design III course offering, likely due to this course being conducted in a compressed environment of a single summer (4½ week) term.

Examples of senior design project technical problems that groups have tackled and thus demonstrated life-long learning skills include (a) process heat integration for a series of evaporators to remove water from ethylene glycol production; (b) evaluation of differences in feedstock and product market values at different locations around the world as a basis for selection of a chemical plant location;

(c) selection of an optimal combination of hydrocarbon products from natural gas feedstock using Fischer-Tropsch synthesis; and (d) development in Aspen of a multi-column distillation system to accomplish product separations associated with a ternary azeotrope system associated with ethyl acetate production. In all of these cases, the life-long learning experience was promoted by the instructor using coaching techniques to guide the students in their search for information and in putting the new information to work to solve their particular design problem, rather than the instructor providing direct answers to their technical questions. Most students seemed to embrace this new learning approach and indicated appreciation for it as the instructor implemented it, principally in the weekly individual design group meetings with the instructor.

Student maturity and unfamiliarity with the professional environment are the challenges that are most relevant to students' acceptance of life-long learning ideals. Many students harbor a misguided concept that, at the time they graduate with a BS degree in engineering, they will know everything that they need to succeed in an engineering job environment. This misconception is discussed by the instructor during the senior design course sequence, in an attempt to have the students understand that they have been taught only a fraction of what they may need in their professional endeavors, and that further learning is required on many projects they will encounter.

## 4. Professional Registration

### 4.1 Course Instruction

The instructor provides information on professional engineering registration in the Design III course principally to raise student awareness and understanding about professional licensure. The information presented is based on several sources including the Texas Board of Professional Engineers, the Texas Society of Professional Engineers, the National Council for Examination of Engineers and Surveyors, as well as the instructor's experience in becoming licensed, and in maintaining licensure, in the States of Texas and Alabama. The relatively low rate of licensure among chemical engineers, as compared to civil engineers, is also discussed. To counter this issue, the benefits of licensure, in particular higher professional status and better employability, are emphasized. The responsibilities associated with licensure, including ethics and continuing professional development, are also discussed. Students are also made aware of the types of jobs for which a PE license would be of little to no use, such as technical sales.

### 4.2 Student Evaluation

At the end of the senior design course sequence, the instructor administers a questionnaire individually to the

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students, with questions ranging from students current success in finding industrial employment to soliciting general comments on the strengths and weaknesses of the chemical engineering department at TAMUK.  One of these questions is about whether the student has taken the fundamentals of engineering (FE) exam, or plans to do so in the future.  The tally of results for this question is presented in Figure 4 for the spring 2017 and summer 2017 cohorts of Design III.  In the spring 2017 class, 18 of 30 students indicated they planned to take the exam, while in the summer 2017 class, 11 of 14 students indicated the same. Thus, roughly 60 to 80 percent of the students are interested in pursuing the start of the PE registration process by taking the FE exam.   This data was not available for the spring 2016 class.  The chemical engineering department does not currently track actual numbers of students who have taken the FE exam.

## 5. Summary

Language barriers, unfamiliarity with the professional work environment, and maturity and experience are challenges that senior chemical engineering students face in improving skills necessary for professional work.  Based on industry work experience and outcomes from 2½ years of instruction in the senior design course sequence, the

instructor has concluded that repetitive assignments (oral presentations and writing assignments), along with constructive feedback in classroom and individual settings, works well to improve student performance in oral and written communication assignments.  The instructor finds that challenging students with technical problems that they have not been exposed to in classroom lectures, and using coaching to guide students to a solution, improves student realization of the need for life-long learning.  Finally, the instructor concludes that relating personal experiences regarding PE licensure and writing assignments improves the student's understanding of the need for, and benefits of, professional engineering registration.
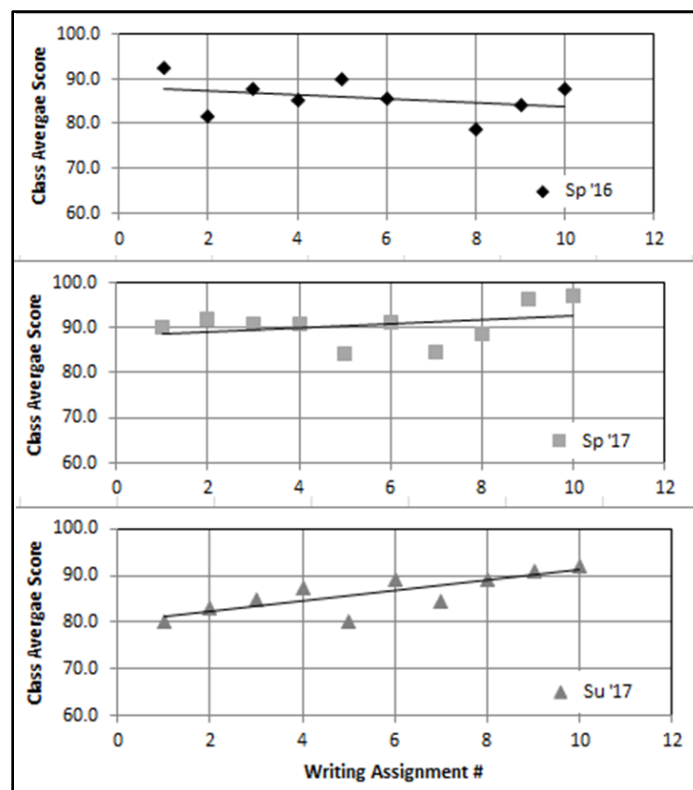
## Acknowledgement

**Fig. 1 Average Student Scores for
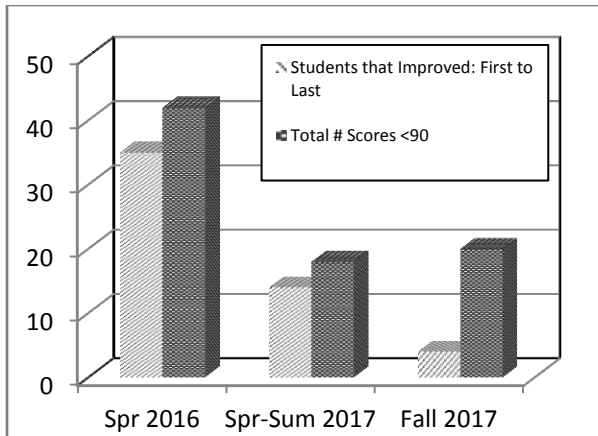Each of Ten Writing Assignments**

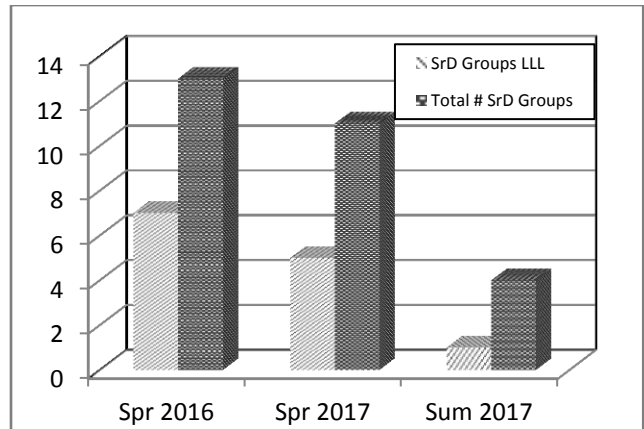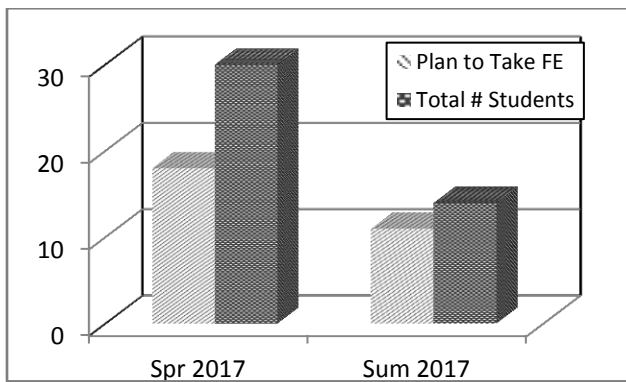**Fig. 2 Student Improvement in Oral Presentations**



**Fig. 3 Students Embracing Life-long Learning**



**Fig. 4 Students Planning to Take FE**

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