ADAPTATION OF PROFESSIONAL SKILLS IN THE UNIT OPERATIONS LABORATORY

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The chemical engineering curriculum ensures students focus on learning the technical details of the profession. Problems in industry, however, involve not only finding technical solutions[1] but also require skills such as proposing ideas, developing practical solutions, working in teams, meeting deadlines, establishing communication between technical support and suppliers, overseeing financial issues, and finally, reporting and presentation skills. Students benefit if a project management and teamwork orientation is introduced to the curriculum.[2,3]

Unit operations laboratory (UOL) courses in chemical engineering curricula have two purposes: firstly, introducing fundamental transport concepts to the students, enabling them to reinforce core courses; and secondly, teaching how to design experiments and think critically about the processes. In industry, engineers are often responsible for practical laboratory issues in order to meet the requirements for experimental data in developing a new product and to test a product to confirm whether the product or design operates as expected.[4] For these reasons, the UOL is considered to be a crucial component of chemical engineering education. While its major goal is to integrate theory and practice, the course also provides an opportunity to design experiments, develop projects, and promote teamwork. Previous studies focusing on the UOL in chemical engineering curriculum either address skills attained[5,6] or discuss the benefits/drawbacks of virtual laboratory compared to hands-on laboratory experiments.[7,9]

Little attention has been paid to the opportunities to teach project management that the UOL course design offers.
This paper presents an innovative course design implemented at a Yeditepe University that has approximately 2,000 students enrolled in the School of Engineering and Architecture. The Department of Chemical Engineering has been approved by the standards established by the Association for Evaluation and Accreditation of Engineering Programs (MUDEK) of Turkey in 2008 for a period of five years. The evaluation process in MUDEK is very similar to that of the Accreditation Board for Engineering Technology (ABET). The university is also a part of the Bologna Process, which aims to standardize higher education curriculum across the European universities with respect to student achievement and quality assurance.

One of the essential components of the Bologna process is to instill lifelong learning in the students. There is a gap, however, in the literature on measuring the lifelong learning course outcomes, which cannot be observed without the feedback of the graduates. Our study contributes to the literature firstly by introducing innovative design of the UOL course and secondly by measuring the course effectiveness by a graduate survey.

**COURSE STRUCTURE**

The UOL courses are placed in the chemical engineering curriculum in three consecutive semesters, starting from the fifth semester. The general framework of the courses and the contents of the UOL courses are presented in Figure 1. The gray box represents the lectures, and rounded rectangles include the topics of the experiments conducted in each UOL course.

The first course of the series, Experimental Chemical Engineering I (UOL1), introduces the general concepts of unit operations. In the first seven weeks, faculty members lecture on unit operations and laboratory safety. By mid-semester, students are assigned to groups and work in teams. The experiments covered in this period mostly involve fluid mechanics and basic separation experiments. During the tenth week, the teams propose two experiments, one of which is chosen as a project proposal to be presented at the end of the semester. Successful completion of UOL1 requires writing a laboratory report, where the project design is a minor concern.

The Experimental Chemical Engineering II (UOL2) course is offered to students who successfully complete fluid mechanics and heat transfer courses in addition to Experimental Chemical Engineering I (UOL1). The students register for UOL2, mass transfer, and reaction kinetics courses simultaneously. Similar to the UOL1 course, the teams offer two project proposals. In this course, a project subject, such as fluid mechanics, heat transfer, mass transfer, or reaction kinetics, is assigned to the teams, which are instructed to propose an experimental design at the end of the semester. The proposal forms the basis for projects in the following and final semester of the UOL courses. The focus of UOL2 shifts to ability to meet deadlines, since approximately 10 experiments are conducted and a laboratory report is submitted each week.

The project proposal is an important part of the course, since at this stage the students learn that the proposed projects will be assigned to the teams in the following course, UOL3, but not necessarily to the team proposing the project. The selection and assignment processes generate a win-win situation, leading all students to design and plan a comprehensive project proposal with the details about the technical specifications and supplier contacts.

The students who successfully complete the transfer courses, UOL1 and UOL2, are eligible to register for the Experimental Chemical Engineering III (UOL3) course. In this final course representative small-scale chemical process units are studied. The projects submitted during UOL2 are expected to be designed and implemented by the students who are now assigned to different teams. All teams have a budget, approximately 200USD, kindly provided by the university to implement the proposed projects. Once the drawing and specification of experimental set-up are completed, the teams are responsible for the correct assembly of the experimental set-up by contacting suppliers. First demonstrations are presented by mid-semester.

The focus of the course content is to design a project in a detailed framework within the allocated budget, which includes purchasing necessary supplies and equipment from business contacts. In order to do so, the students assume full responsibility for contacting suppliers and define technical specifications. Until the delivery of the purchased equipment, the teams complete the background study on experimental design. Following the delivery of equipment and materials around the eighth week of the semester, the teams start conducting their experiments and deal with the technical problems that may result from improper design of experimental set-up. The experimentation stage is completed approximately within the third month of the
academic semester. After the collection of experimental data, the students analyze their results as well as prepare laboratory reports.

**Skills Gained Through Projects**

In the UOL1 and UOL2 courses, teams propose two experiments, and the selected proposals are presented at the end of the semester. In the UOL3 course, the selected projects are designed and conducted by the students. The selection process encourages UOL1 and UOL2 students to pay attention to the details, such as specifications of the experimental set-up and calculations.

During the UOL3 course, approximately four weeks at the end of the semester are allocated for the projects. To complete the course requirements, the students tackle tasks including: project design, project planning, preparation of experimental set-up, experiment design, report writing, and presentation. Project design is an important component of the process: the students work on the necessary background and determine experimentation needs, equipment availability, and chemicals. The content encourages students to learn business transactions, invoice terms, and how to purchase the laborato-

tory chemicals and equipments as well as design of experimental set-ups. Students are expected to apply multitasking skills: dealing with the project design and implementation is handled concomitantly with the experiments and preparation of laboratory reports.

At the end of the semester, all UOL teams present their work. Reserving one day for all UOL project presentations has two purposes: first is to enable the UOL1 and UOL2 students to observe the stages of a project implementation and benefit from the experience of the UOL3 students; second is to enhance communication among junior and senior students. A representative calendar for three of the courses is provided in Figure 2, explaining the experiments conducted. In this table, the gray boxes represent the lectures or class hours. The rounded rectangles represent the laboratory experiments. The three-hour course duration is marked at the end of the table. UOL1 starts with the lectures of fluid mechanics (FM), heat transfer (HT), mass transfer (MT), reaction kinetics (RK), and laboratory safety. The ChemCAD (CC) lectures in UOL1 are performed in computer laboratories. All three courses also have experiments on basic separation (BS) and bioprocesses (BIO). The final four weeks of UOL3 are allocated to project experiments. During these weeks, the students prepare bioprocess (BIO) experiments in the first hour and conduct their project experiments in the remaining hours.

**Evaluation of the projects**

The project evaluations are conducted in a hierarchical structure. Each student of UOL1 is assigned two referee students: a senior student enrolled in the UOL3 course and a junior student enrolled in the UOL2 course. Similarly, each student of the UOL2 course is assigned a referee student enrolled in the UOL3 course. This structure allows senior students to evaluate the presentations of the junior students and discuss potential caveats in the project proposals; in return, the UOL1 students observe how to ask and answer questions in a formal presentation.

This evaluative framework enhances understanding of concepts, project design, and implementation. It was previously reported that involving the students in the task of assessment not only fosters skills of professional judgment but also increases the reliability of the assessment.12

After each team’s presentation, the referee asks questions to the presenters.

![Figure 2. Example calendar for unit operations courses.](image-url)
about the background and caveats of the project. A student's performance as a referee is called offense. A student's knowledge on answering the questions after his/her presentation is called defense. Hence, the evaluation form is designed to reflect a multi-scale evaluation. Each student's performance is a combination of (i) individual presentation performance, (ii) team performance (which is a unique score for the team), (iii) defense (according to ability in answering the questions), and (iv) offense (according to his/her performance as a referee, which is a separate score). The results of the evaluation forms are then averaged, and the students are informed of their evaluation scores and the average presentation scores for the course.

The UOL1 students only evaluate and grade themselves, UOL2 students evaluate UOL1 students and themselves, and UOL3 students evaluate all of the students. Invited faculty and teaching assistants use the same evaluations scheme for UOL3 students. Figure 3 depicts the hierarchical evaluation structure employed during the presentations. From the perspective of students evaluating themselves, the UOL1 and UOL2 projects are questioned by UOL2 and UOL3 students, yet UOL3 projects are evaluated by instructors, teaching assistants, and the students enrolled in the UOL3 course.

Two additional evaluation forms are distributed: one for the evaluation of the teaching assistants, another for the evaluation of the students themselves as teammates during the semester. The evaluations about teaching assistants, who are involved in experiments and projects as junior supervisors, enable students to evaluate supervisor performance. The second type of evaluation form asks students to evaluate their teammates and their own performance during the semester and the projects, thereby enabling students to evaluate self-performance and the performance of their teammates. The results of the teaching assistant evaluations are shared with the assistants at the end of the semester. Self- and teammate evaluation form results are considered as feedback for group assignments for the following semester.

RESULTS

This elaborate evaluation mechanism across the three consecutive UOL courses positions students to be well-prepared for professional life in managing teamwork and projects, meeting deadlines, and presenting and defending their work, as well as in evaluating other team members and supervisors. Identifying whether the course design helps students attain these skills requires a follow-up survey targeting the graduates of the department. For this purpose, we designed a survey consisting of 52 questions. The survey was disseminated between June 2010-August 2010 through an online portal by inviting all graduates via e-mail. The Department of Chemical Engineering was established in 2001, while first graduation was in 2005. Among the total number of 115 graduates, 58 responded to the questionnaire. We later contacted graduates who did not respond to the survey and inquired about the reasons for non-response. The majority of the students reported computer access and net connection problems, allowing us to confirm non-responsiveness did not cause selected sample properties in our surveyed population.

We also compared the characteristics of the survey population with the population of the graduates, using available administrative student records. As summarized in Table 1, the population that responded to the survey is representative of the student population graduated from the department by demographic characteristics and by high school status. For instance, of the 58 students, 76% are female, whereas in the graduate population, this ratio is 73%. The sampled graduates have somewhat a lower share of students with scholarships,

| TABLE 1 |
|-----------------|-----------------|-----------------|
| The characteristics of graduates who participated in the survey compared to all chemical engineering graduates | Graduate population averages (stdev) | Sampled graduates averages (stdev) |
| Sex (F=1, M=0) | 0.73 (0.4457) | 0.76 (0.4317) |
| Hometown (Istanbul=1, Other=0) | 0.47 (0.5013) | 0.48 (0.5041) |
| High school (Public=1, Private=0) | 0.55 (0.4999) | 0.57 (0.4995) |
| Scholarship status (Full=2, Partly=1, None=0) | 0.76 (0.7205) | 0.64 (0.6675) |
| CGPA | 2.60 (0.4989) | 2.74 (0.5060) |
| Semesters until graduation | 8.8 (1.6889) | 8.5 (1.4414) |
| Years after graduation | 1.63 (1.28) | 1.88 (1.39) |
The distribution of the graduates according to employment

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate School</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turkey (9), Europe and USA (6)</td>
<td>15</td>
<td>25.86</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw chemical (15), Pharmaceutical (11), Consumer Goods (4), Real Estate (2), Food (2)</td>
<td>34</td>
<td>58.62</td>
</tr>
<tr>
<td>Unemployed</td>
<td>9</td>
<td>15.52</td>
</tr>
<tr>
<td>TOTAL</td>
<td>58</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Selected questions from the survey evaluating the skills attained during UOL courses

Could you rate the professional skills you attained in these courses? Please mark the appropriate scale from 1 to 5, 1 indicating "none," 5 indicating "absolutely"

<table>
<thead>
<tr>
<th></th>
<th>UOL1</th>
<th>UOL2</th>
<th>UOL3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Design</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Project Planning</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Teamwork</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Meeting Deadlines</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Report Writing</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Presentation</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</tbody>
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At which stage of your work experience, did you make use of these skills? Please mark all that apply.
- Job interview
- Research
- Product / technology development
- Prototyping / test production
- Production
- Publicity
- Sales
- Logistics
- Never
- Other

Compared to other courses, which skills are specific to unit operations laboratory courses? Please mark all that apply.
- Learning business transactions
- Managing project budget
- Negotiation with outside suppliers
- Establishing professional contacts
- Public speaking
- Critique own work
- Evaluating team members
- Evaluating supervisors
- Developing my research agenda
- None
- Other

Did you use any of these skills in your daily life? Please mark all that apply.
- Self motivation
- Scheduling daily life
- Time management
- Self confidence
- Critical thinking
- Speaking in English
- None
- Other

The survey begins with asking the graduates about their employment status. Out of 58 graduates, 34 of them are employed in industry, 15 of them pursue advanced degrees (six students are enrolled in graduate programs in Europe and the United States, nine are enrolled in graduate programs in Turkey), and the remaining nine students were unemployed at the time they responded to the survey, the majority of whom are 2010 graduates seeking employment. The distribution of the graduates according to employment status is presented in Table 2.

Participating program graduates are asked to evaluate the UOL courses by the attributes, which reflect the skills incorporated into the course design. We group these attributes under the headings of project design, project planning, working in teams, meeting deadlines, report writing, and presentation. The survey then inquires if and at what stage of their work experience the participating graduates have used these skills. Finally, the survey included questions on whether the students rely on these skills in their daily life, gauging the extent to which the outcomes fulfill the lifelong education premises. A sample of survey questions is summarized in Table 3.

Considering that students who attend a Masters or Ph.D. program may need a different set of skills than the participants employed in the industry, we separated our analysis into two groups: the graduates pursuing an academic degree, and graduates working in industry, leaving the job-seeking graduates out. The analysis presented in the rest of the paper therefore summarizes the survey results obtained from these two groups of students.

We also asked the graduates at what stage during their post-graduation careers they have relied on the skills introduced in the UOL courses. The results, displayed in Figure 4, show that the skills gained during UOL courses are not only valuable for job interview and research, but also at various stages of their professional life, including sales, publicity, product development, and logistics. Recalling that our analysis in-
volves two sets of graduates (academia and industry), in this figure, frequency shows the number of students that selected a particular answer to the number of students in the corresponding cohort. Approximately 30% of the graduates employed in industry replied that the skills proved to be valuable during job interviews. The response rate for the job interview for the graduates pursuing M.Sc. and Ph.D. degrees in academia is too low, since acceptance to a post-graduation program relies on, first and foremost, academic achievement. In this group, however, approximately 85% report that they found the skills useful for conducting research.

Considering it is also possible that similar skills are taught in the other courses of the curriculum, the survey then inquiries about the skills that are attained solely through the UOL courses. These UOL-specific skills are divided into two subsections: professional relations and professional skills. Learning business transactions, budgeting, establishing business contacts, and negotiating with suppliers are considered as a part of professional relations. The results are presented in Figure 5. In terms of professional relations, learning business transactions and establishing professional contacts are the two aspects that are most important for the graduates employed in industry. Like graduates employed in industry, the survey participants who pursue academic careers also reported to rely on conducting business transactions and negotiating with suppliers frequently, which can be a result of working in a laboratory.

The professional skills acquired through the UOL courses include public speaking, self-criticism, and evaluation of team members and supervisors. Figure 5 also summarizes the results pertaining to this set of skills. Public speaking is frequently required for the graduates pursuing degrees in academia, such as presenting their research in various conferences and research meetings. The graduates placed in academia frequently reported this skill as gained through the UOL courses, compared to the graduates employed in industry. The graduates were also asked if unit operations laboratory is useful to gain self- and peer assessment skills, which is an important part of engineering education. Self-evaluation was previously incorporated into team process by completing a self-evaluation form as a part of project reports. This study showed that self-assessment not only enhances self-awareness but also helps the students to overcome learning obstacles. On the other hand, peer evaluation was used for summative purposes to promote seriousness and commitment. The results showed that the graduates pursuing advanced degrees are more likely to criticize their own work, which is likely due to the fact that in industry the employees are mostly evaluated by their supervisors. A significant difference between the two groups is observed in team-member evaluation skill. Relatively more graduates placed in advanced programs report this skill as useful compared with their peers in industry. This difference can be explained by the competitive academic environment where evaluation and feedback mechanisms are required for an actively collaborative research agenda.

As a final evaluation, we asked the participating graduates of the department if, in their daily lives, they rely on the skills they acquired in the UOL courses. The results are shown in Figure 6 (next page). For both groups self-motivation and time management are two comparatively valuable skills. Scheduling daily life is reported to be an important skill for
graduates in industry compared with the graduates placed in academia. A significant difference in the answers between the two groups is observed in self-confidence. This result may reflect that the graduates who continue their post-graduate studies find themselves in a heterogeneous and scientifically competitive environment.

The results reveal that with the skills gained during the UOL courses, the graduates employed in industry are well equipped and well prepared for professional life. A skill that is important for the graduates employed in industry is critical thinking, which is crucial to develop new strategies. Speaking in English is another aspect that is reported by the graduates in industry, implying that the rigorous presentation schedule and public speaking required by the UOL course design are sufficient for the professional work environment.

CONCLUSION

The studies on the UOL course design have tended to focus exclusively on the curriculum design and the laboratory experiments. We contributed to the literature with describing the innovative design of the UOL course offered by the Chemical Engineering Department at Yeditepe University in Turkey. The course design, in addition to retaining academic rigor of the UOL courses, supplements the students with additional career-oriented skills. To measure course outcomes, a survey targeting the graduates of the program is implemented. The survey results reveal graduates employed in industry rely on these skills in job interviews, research, and product development. For graduates who attend post-graduate programs, the skills help during their research. Furthermore, the results also show that the lifelong learning objective of the Bologna process is achieved. While we acknowledge that in the future, studies examining course outcomes in different institutional contexts are needed, we argue that the UOL course offers an innovative platform for achieving course outcomes that introduce the skills necessary for post-graduation careers. Finally, these results indicate that the participating graduates who pursue advanced degrees may use skills different from the skills used by graduates employed in industry, highlighting the need of an adaptive approach in meeting different professional career goals of the students.

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REFERENCES


Figure 6. Skills used to regulate daily life.