AC 2011-236: INTRODUCING PROFESSIONAL SKILLS DURING UNIT OPERATIONS LABORATORY

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Introducing Professional Skills during Unit Operations Laboratory

Abstract

Unit operations laboratory (UOL) course is considered to be a crucial and integral part of the chemical engineering education. The primary objective of the course is to enable students to combine theory and practice. Problems in industry however entail more than finding technical solutions. Indeed professional life requires other skills such as an ability to propose ideas, develop practical solutions, participate in teamwork, meet deadlines, establish communication between technical support and suppliers, oversee financial issues, and finally reporting and presentation skills. This study describes how in three consecutive courses, we preserve academic rigor of the UOL course while incorporating components such as experimental design, project development and teamwork, which aim to meet the needs of professional careers. We follow up the course outcomes with a survey targeting the graduates of the program. The results show that graduates employed in industry frequently rely on these skills during job interviews, research and product development, whereas those who pursue advanced degrees in academia use these skills predominantly for their research, highlighting the need for adaptive approach for different graduate trajectories in designing the course. For both groups of graduates, the skills introduced during the UOL courses are reported to be valuable in their daily life, emphasizing life-long learning.

1. Introduction

Chemical engineering curriculum ensures students focus on learning the technical details of the profession. However, problems in industry always involve much more than just finding technical solutions.[1] Professional careers 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. Very few chemical engineering programs incorporate project management courses that meet requirements of professional life. Therefore, alterations and additions into the existing curriculum are needed. Students benefit if a project management and teamwork orientation is introduced to the curriculum. [2, 3]

In this study, we describe the design of the three consecutive Unit Operations Laboratory (UOL) courses offered by the Department of Chemical Engineering at Yeditepe University, Istanbul, Turkey. The course design introduces professional skills while preserving the core components of the UOL courses. We track the course outcomes with a graduate survey to assess the effectiveness of additional components introduced in course design. Our paper contributes to the literature firstly by innovative design of a UOL course and secondly by measuring course effectiveness by a graduate survey. The paper starts with describing the institutional environment and proceeds with the section on the specific design of UOL courses. In the penultimate section we describe the survey population and analyze the results pertaining to course outcomes. The final section concludes with a summary of our findings.

2. Description of the institutional environment

Private universities in Turkey are owned by non-profit foundations as stated by the law under the supervision of Council of Higher Education. The university currently has 12 schools with 59 departments. As of 2010, the undergraduate student population is approximately 14,000 students and 2,000 (13.5%) of these students are in School of Engineering and Architecture. The duration of the engineering education is four years (eight semesters) and minimum graduation requirements are the successful completion of about 145 credits (~50 courses) with a cumulative grade point average of 2.00 over 4.00. The Department of Chemical Engineering was established in 2001 with student admissions of 30 per year. Currently, 70 out of 630 engineering students, which is the total quota of the engineering school, are being admitted to the Department of Chemical Engineering.

The undergraduate chemical engineering curriculum is categorized under basic sciences, engineering sciences, core chemical engineering courses, and non-major courses such as, engineering management, law and humanities. The Chemical Engineering program has been approved by the Association for Evaluation and Accreditation of Engineering Programs (MUDEK) of Turkey in 2008 for a period of five years. [4] The evaluation process in MUDEK is very similar to that of Accreditation Board for Engineering Technology (ABET). MUDEK is also a full member of European Network for Accreditation of Engineering Education (ENAEE) and is authorized to award EUR-ACE (European Accredited Engineer) label to the graduates of approved departments. [5]

As stated in the original declaration of Bologna Process [6] and agreed by most of the European universities, higher education across European countries is standardized with respect to student achievement and quality assurance. One of the essential components of the Bologna process is to encourage life-long learning skills. A crucial component of this endeavor is to follow the graduates and to observe whether the stated outcomes of an undergraduate curriculum are met following graduation.

3. Course Structure

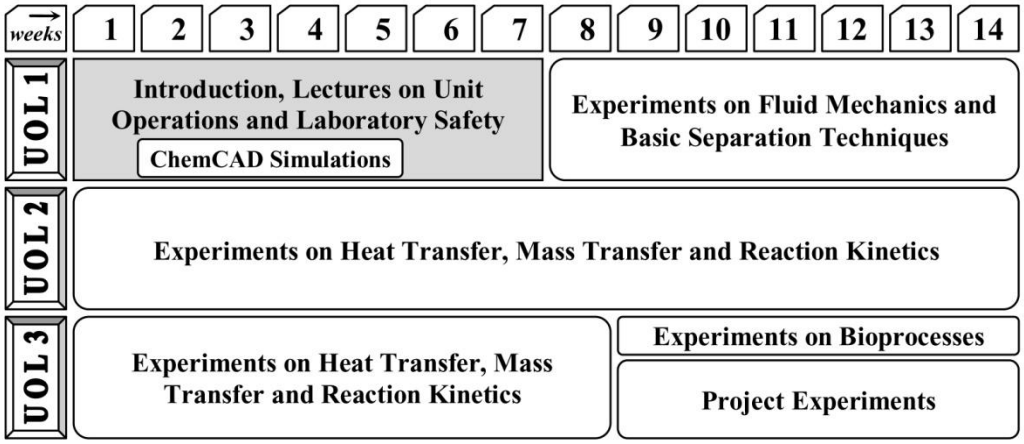
The three consecutive UOL courses offered in chemical engineering curriculum have two purposes: firstly, introducing fundamental transport concepts to students enabling them to reinforce core courses and secondly, teaching how to design/implement experiments and lastly emphasizing critical thinking on 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 whether the product or design operate as expected.[7]

For these reasons, the UOL is considered to be a crucial and integral part of the chemical engineering education. While its major goal is to provide students a suitable platform to integrate theory and practice, the course also allows an opportunity for designing experiments, developing projects and promoting teamwork. Previous studies focusing on the importance of UOL in chemical engineering curriculum generally address skills attained [8, 9] or discuss the benefits or drawbacks of virtual laboratory compared to hands-on laboratory experiments. [10-12] In this study, we describe the course design in which skills relevant for the demands of professional careers are

introduced. As stated, there is a gap in the literature of measuring the course outcomes which cannot be observed without the feedback of the graduates. In addition to describing the innovative design of the course, this study also aims to fill this gap in the literature.

The UOL courses are placed in the chemical engineering curriculum in three consecutive semesters, starting from the fifth semester. Similar to all other courses at School of Engineering and Architecture, these three courses are offered in each and every semester. These three UOL courses aim to teach the unit operations as well as offer an opportunity to prepare the students for professional experience. The experiments performed in the UOL courses follow the requirements of the core chemical engineering courses and the continuity of the courses is maintained by corresponding prerequisite courses. The general framework of the courses and the contents of the UOL courses are presented in Table 1. The gray box represents the lectures, and rounded rectangles include the topics of the experiments conducted in each UOL courses. The first seven weeks at the beginning of the semester of UOL1 is allocated for lectures, whereas the students conduct laboratory experiments in the remaining seven weeks. The detailed descriptions of the components in each UOL courses are explained below.

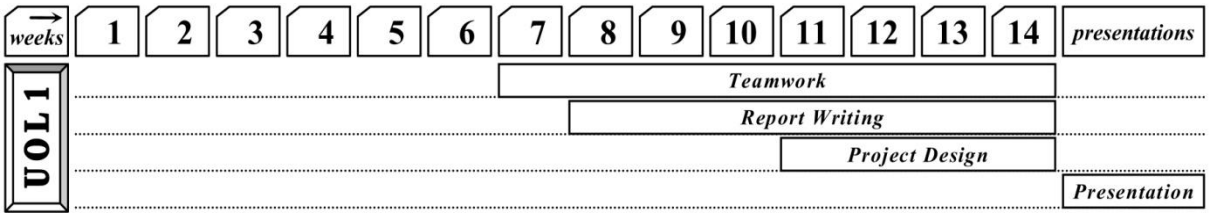
Table 1: General framework of the UOL courses, the lectures are indicated with the gray box, the topics of the laboratory experiments conducted are presented in rounded rectangles.



First course of the series, the Experimental Chemical Engineering I (UOL1) course, introduces the general concepts of unit operations. In the first seven weeks, faculty members lecture on unit operations and laboratory safety. In addition, in this period the students are expected to study single unit systems simulated with ChemCAD. At 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. At the 10^{th} week, the teams propose two experiments, one of which is chosen as a project proposal and the team members are then expected to present the project at the end of the semester. Successful completion of UOL1, the first course in the series, requires writing a laboratory report, where the project design is a minor concern. For the first time during their Chemical Engineering education, the students perform experiments and submit their reports as teams, which introduce teamwork skills. A laboratory report is submitted each week, which in turn is reviewed and returned back to the team members in order to support progress in report

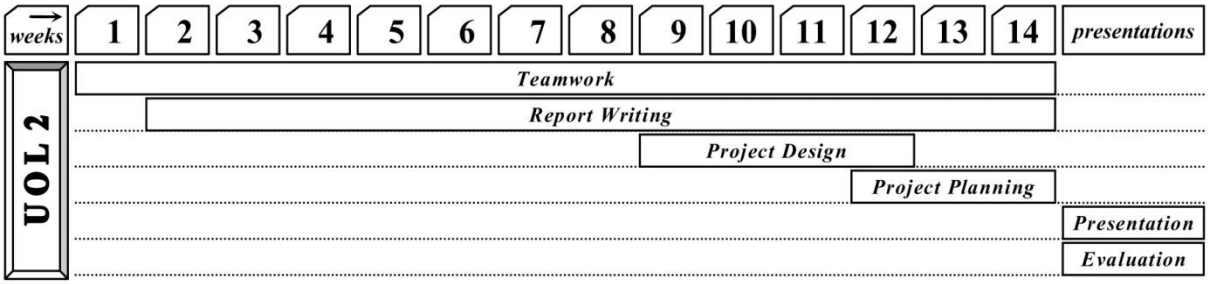
writing skills. The skills introduced during the UOL1 course across the semester are presented in Table 2.

Table 2: The skills introduced during UOL1 course on a weekly basis.



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 generally register for UOL2, mass transfer and reaction kinetics courses simultaneously. A total number of 10 experiments, focusing on heat transfer, mass transfer and reaction kinetics, are conducted by teams. Similar to the UOL1 course, the teams offer two project proposals. In this course, only the general focus area is assigned to teams, such as fluid mechanics, heat transfer, mass transfer and reaction kinetics. The teams are instructed to propose an experimental design and present a proposal at the end of the semester. The proposal constitutes the basis for experiment design in the following and final semester of the UOL courses. By this second course, UOL2, the students are experienced in teamwork and know to handle communication problems and to distribute tasks according to the ability of each team member. The focus of UOL2 shifts onto the ability to meet deadlines, since approximately 10 experiments are conducted and a laboratory report is submitted each week. The project proposal part becomes 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 design and plan a comprehensive project proposal with the details about the technical specifications and supplier contacts. Table 3 represents the skills introduced during UOL2.

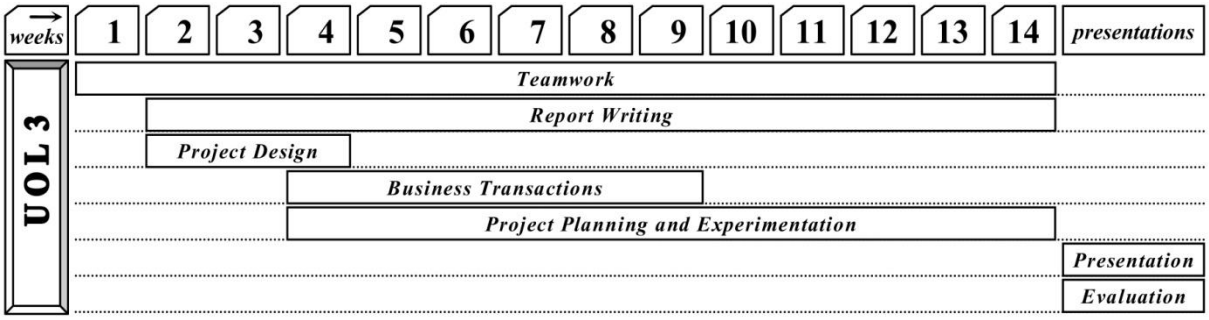
Table 3: The skills introduced during UOL2 course on a weekly basis.



The students who successfully complete the transfer courses, UOL1 and UOL2, are eligible to register for Experimental Chemical Engineering III (UOL3) course. This final course aims to provide students representative small scale units to study the fundamental chemical processes, such as distillation, liquid-liquid extraction and gas absorption. In this course, the projects

submitted during UOL2 are expected to be designed and conducted by the same students who are now assigned to different teams. During the first four weeks of the academic semester, the students are expected to do research. All groups 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. Following the comments of the assistants and the instructor, the experimental set-ups are fixed or fine-tuned accordingly. During the semester the groups submit two progress reports in which they explain and analyze each step encountered. In the UOL3 course, final course of the UOL series, the focus of 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. At this stage, the team members learn how to deal with business transactions, invoice terms, and how to purchase the laboratory chemicals and equipments as well as design of experimental set-ups. These processes also encourage students to apply multitasking skills as well: while dealing with the project design and implementation, the students are expected to perform experiments and prepare laboratory reports. Table 4 represents the skills introduced during UOL3 course.

Table 4: The skills introduced during UOL3 course on a weekly basis.



3.1. Selection of Teams

The UOL courses are designed to ensure the students gain different sets of skills at each course and offer an excellent environment to develop teamwork skills. The ways in which the students are assigned to groups vary however. Some instructors prefer students decide their team members, some prefer random assignments and selection by the cumulative GPA, either cluster students into high grade to low grade or adjust the teams to have one high / one low grade student are other possibilities. Our strategy by which the students assigned in proposed course design takes cumulative GPA as its benchmark. The students are clustered around the average cumulative GPA of the class and in each group contains a student with higher academic achievement (CGPA > 3.00) and a student with lower achievement (CGPA < 2.00). Since the students are reassigned to teams in each of the UOL courses, all students have a chance to work with other peers with varying academic achievement levels prior to their graduation. According to our observations on group dynamics, the students with lower academic grades are encouraged to study more and have a chance to enhance team performance with their abilities other than academic skills. On the other hand, students with higher cumulative GPA learn to manage the whole group and supervise their own research.

3.2. Project Proposals

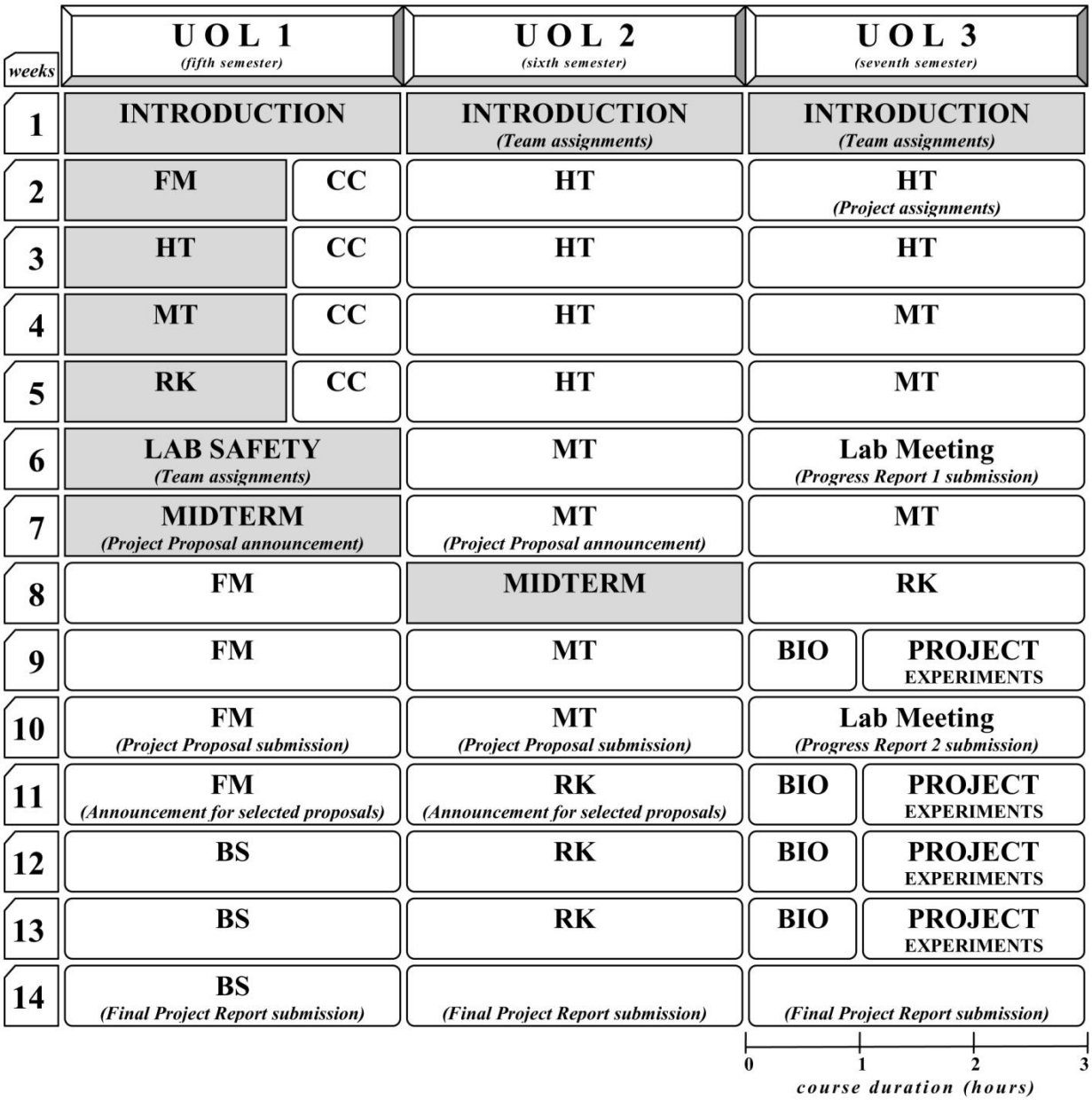
In the UOL1 and UOL2 courses, teams propose two experiments and the selected proposals are presented at the end of the semester. During the last UOL course, UOL3, the projects proposed and selected in previous semesters are designed and conducted by the students. The selection process encourages UOL1 and UOL2 students to pay attention on the details, such as specifications of the experimental set-up and calculations. One teaching assistant is assigned as a mentor for each of the projects to be implemented in the UOL3 course.

During the UOL3 course, approximately four weeks at the end of the semester are allocated for the projects. The same period is also scheduled for bioengineering experiments, which generally require one hour of preparation followed by hourly data collection for the rest of the day. Therefore one hour laboratory is allocated for bioengineering experiments and in the remaining two hours, the teams study on their projects. To complete the course requirements, the students tackle tasks including: project design, project planning, and 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. During this stage, the groups start planning experimental conditions to be tested in the project. At the end of the 3rd week, the teams are expected to be ready to purchase the materials for their project. In order to do so, the students assume full responsibility to contact suppliers and define technical specifications. Until the delivery of the purchased equipments, the teams complete the background study on experimental design. Following the delivery of equipment and materials around the 8th week of the semester, the teams start conducting their experiments and deal with the technical problems which 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.

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 UOL3 students' experience; second is to gather junior and senior students in a one day event and enhance communication. According to our observations, there is an obvious progress in the students' presentation techniques during UOL courses.

A representative calendar for three of the courses is provided in Table 5, 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.

Table 5: Example calendar for unit operations courses.



3.3. Evaluation of the projects

As mentioned above, at the end of each semester, all groups in UOL three courses present their proposals and projects on the same day reserved for the UOL courses. Junior students observe the senior students during presentations and learn about professional details, including business transactions, problems faced during the preparation and manufacturing of experimental set-ups. Each student of UOL1 is assigned two referee students: a senior student enrolled to the UOL3 course and a junior student enrolled to the UOL2 course. Similarly, each student of UOL2 course is assigned a referee student enrolled to 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 hierarchical structure of evaluative framework enhances understanding concepts, project design and implementation. On the project presentation day during the final exam period, the program is announced and the presentations are grouped by subject headings such as fluid mechanics and heat transfer.

The evaluation process is designed as follows. After each team's presentation, the referee asks questions to the presenters about the background and caveats of the project. A student's performance as a referee is called as offense. On the other hand, a student's knowledge on answering the questions after his/her presentation is called as defense. The presentation is expected to carry interest for the audience and the student is expected to be presentable, such as speaking fluently. 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 the ability of 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 hierarchical structure of the evaluations is as follows: UOL1 students only evaluate and grade themselves, UOL2 students evaluate UOL1 students and themselves, UOL3 students evaluate all of the students. Invited faculty and teaching assistants use the same evaluations scheme for UOL3 students. Figure 1 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 UOL3 course.

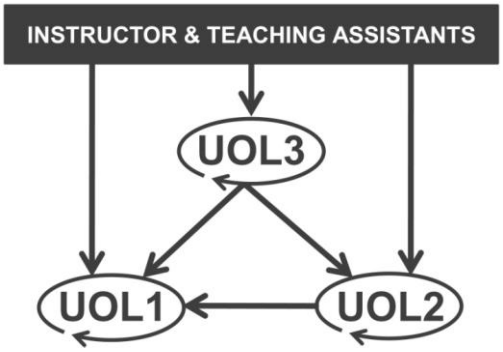


Figure 1: Schematic representation of the evaluation process during the project presentation day

3.4. Other evaluations

At the end of the presentation day, two additional evaluation forms are distributed; one for the evaluation of the teaching assistants, another for the evaluation of the students themselves as team mates during the semester. The generic course evaluation forms, inquiring about the instructor, the course and the infrastructure of laboratories, are distributed to students during the final exam. These generic student evaluations do not include evaluations of teaching assistants,

who are directly involved in experiments and projects of the UOL courses. Therefore, student evaluations of teaching assistants are considered to be an important input in the course design. The questions evaluating the performance of the teaching assistant are provided in Table 6. We believe this inquiry enables students to evaluate supervisor performance.

Table 6: Inquiry about the performance of the teaching assistants.

Rate over 10 (1 - very poor .. 10 - very good)
1. Technical knowledge on experiments
2. Performance during office hours and laboratory
3. Finding practical solutions to experimental problems
4. Fairness of grading laboratory reports
5. Availability at school
6. Availability with e-mail
7. Communication skills when interacting with students
8. Overall performance

The second type of evaluation forms used on the presentation day requires students to evaluate their team mates and their own performance during the semester and during the projects. This questionnaire, in Table 7, enables students to evaluate self-performance and the performance of their team mates.

Table 7: Inquiry about the performance of the teammates

Rate over 10 (1 - very poor .. 10 - very good)
1. S(he) has completed perfectly every part of laboratory ***reports*** that s(he) was responsible
2. S(he) was eager to help other partners on their parts
3. S(he) contributed her/his intellectual aspect on each experiment, (recommendations, brainstorming)
4. S(he) has completed the tasks in the ***project*** by the time which was agreed by the group
5. S(he) practiced good communication skills with other partners. (S(he) was available each time)
6. Her/his contribution to lab reports was (Whole group should sum up to 100)
7. Her/his contribution to the project was (Whole group should sum up to 100)

The results of the teaching assistant evaluations are shared with the assistants at the end of the semester. Self and team mate evaluation form results are considered as feedback for group assignments for the following semester.

4. Results

This elaborate evaluation mechanism across the three consecutive UOL courses aims students to be well-prepared for professional life in managing teamwork and projects, meeting deadlines, presenting and defending their work, as well as in evaluating other team members and supervisors. The extent to which the course design enables students to attain these skills requires a follow-up survey targeting the graduates of the department. To measure the learning outcomes of these three UOL courses in relation to preparing students to professional life, we designed a survey consisting of 52 questions. The survey was disseminated through an online portal by inviting graduates via e-mail. Among 115 graduates, 58 responded to the questionnaire. We later contacted graduates who did not respond the survey and inquired about the reasons of non-response. The majority of the students reported internet connection problems as a reason and although they started answering the questionnaire, they were unable to finish due to firewall protection implemented on their internet connection. The answers regarding the non-responsiveness confirmed that the population who did not participate in the survey does not exhibit selected sample properties.

We also compared the characteristics of these two groups to further ensure the sampled population of graduates is similar to the population of the graduates, using available administrative student records. As summarized in Table 8, the population 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, 75% are female, whereas in the graduate population, this ratio is 73%. The sampled graduates have somewhat a lower share of students with scholarships, compared to the same share of the graduates with scholarships within the graduate population. Furthermore the average cumulative GPA of participating graduates, 2.74, is slightly higher than the average cumulative GPA of the total graduate population. With respect to the time to graduate, again the sampled population graduated on average at 8.5 semesters whereas the average number of semesters of the graduate population is slightly higher, 8.8 semesters.

Table 8: The characteristics of graduates who participated in the survey compared to all chemical engineering graduates

	Graduate population Averages (*stdev*) *n* = 115	Sampled graduates Averages (*stdev*) *n* = 58
Sex (F=1,M=0)	0.73 (*0.4457*)	0.76 (*0.4317*)
Age at graduation	23.93 (*1.4438*)	23.62 (*1.4302*)
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	8.8 (*1.6889*)	8.5 (*1.4414*)

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 enrolled in graduate programs in Europe and the USA, nine are enrolled in graduate programs in Turkey), and the remaining nine students are unemployed at the time they responded the survey. The distribution of the graduates according to employment status is presented in Figure 2.

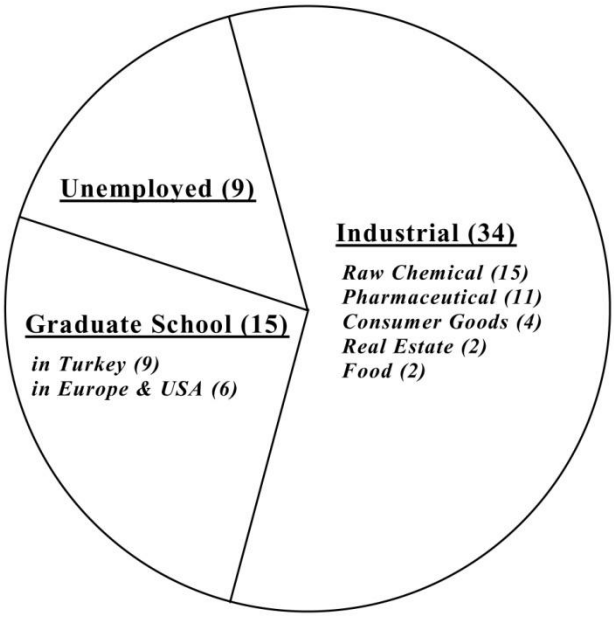


Figure 2: The distribution of the graduates according to employment status

Participating program graduates are asked to evaluate the UOL courses by the attributes which reflect the skills incorporated into the course design. We grouped 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. Considering some of these skills are also taught in other departmental courses, the survey also asks which skills are specific to the UOL courses. Finally, the survey included questions on whether or not the students rely on these skills in their daily life, an expectation that the course outcomes fulfill the life-long education premises intended by the Bologna process. A sample of the questions is summarized in Table 9.

By the employment status, the survey results reveal three different sets of graduates. The first group, majority of whom are 2010 graduates, report they are seeking for employment. These students are in the process of beginning their professional careers; it may take up to a year to be placed in a job. Within the remaining two sets, majority of graduates have been employed in the private sector, and a non-negligible number of graduates of the department pursue advanced degrees. Considering the graduates who attend a Masters or PhD program may need different set of skills than those employed in the industry, we separated our analysis into two groups: graduates pursuing an academic degree and graduates working in the industry. The analysis presented in the rest of the paper therefore summarizes the survey results obtained from these two groups of students.

The survey asks the graduates at what stage during their post-graduation careers they have used the skills incorporated into the UOL courses. The results are shown in Figure 3. Approximately 30% of the graduates employed in industry replied that the skills proved to be valuable during job interview. These results, categorized and depicted in Figure 3, also 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. The response rate for the job interview for the graduates pursuing MSc and PhD degrees in academia is too low, since acceptance to a post-graduation program relies first and foremost on academic achievement. In this group, however, approximately 85% report that these skills are useful for conducting research.

Table 9: 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”

	UOL1	**UOL2**	**UOL3**
Project Design	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5
Project Planning	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5
Teamwork	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5
Meeting Deadlines	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5
Report Writing	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5
Presentation	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5	1 □ □ □ □ □ 5

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

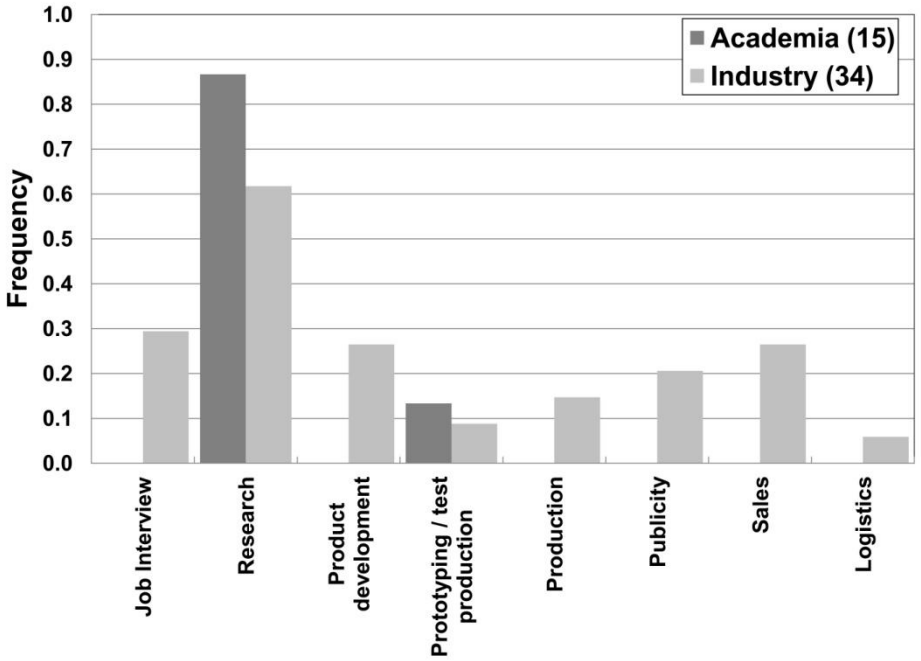


Figure 3: Skills experienced at different stages of professional life

Considering the possibility that similar skills are taught in the other courses of curriculum, the survey then asks the graduates about the skills that are attained solely through the UOL courses. These skills that are specific to the UOL courses 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; whereas public speaking, criticism of own work, evaluation of team members / supervisors and establishing own research agenda are considered as the parts of professional skills. The results are presented in Figure 4.

In terms of professional relations, learning business transactions and establishing professional contacts are the two aspects that are important for the graduates employed in industry. The survey participants who are placed in graduate programs are more likely to rely on conducting business transactions and negotiating with suppliers which can be attributed to laboratory work environment. The graduates employed in industry mostly work in other departments, such as production, sales and logistics departments; hence the need to communicate with suppliers may not be an important part of their professional responsibilities.

The professional skills acquired through the UOL courses are more useful than the professional relations for both of the groups. Figure 4 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. Therefore more of the graduates placed in academia reported this aspect as a skill gained through the UOL courses, compared to the graduates employed in industry. Furthermore, the graduates pursuing advanced degrees are more likely 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 attributed to the competitive academic environment where evaluation and feedback mechanisms are considered to be a component of an actively collaborative research agenda. Considering the skill of establishing own research agenda; the graduates in industry report that this skill is more valuable compared with their peers in academia. This can be explained by the fact that graduates in academia generally follow the research agenda of their academic group. However, the graduates in industry, particularly working in product development departments, may need to establish their own research agenda.

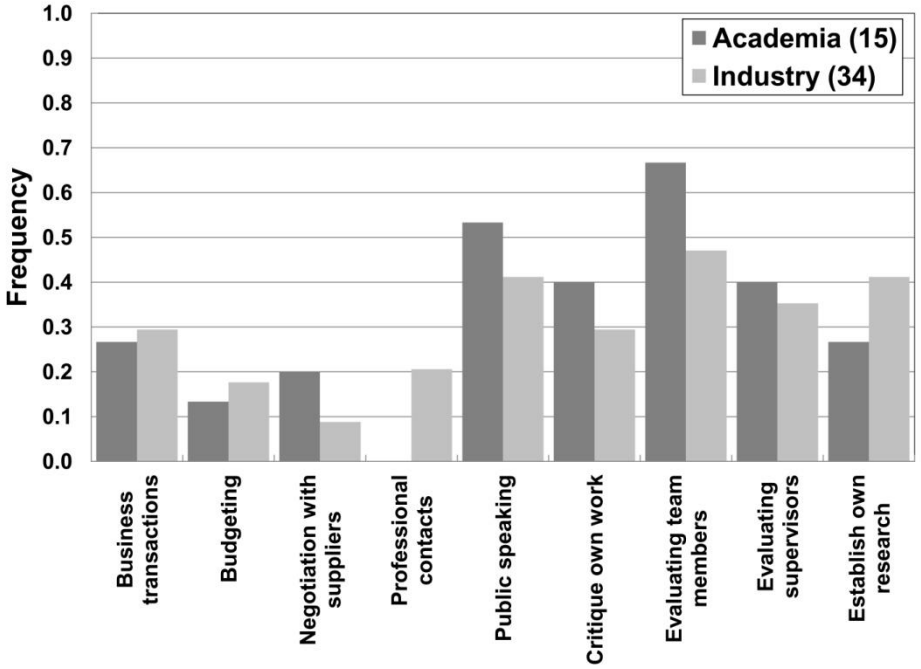


Figure 4: Skills that are specific to unit operations laboratory courses and relevance in professional life

As a final evaluation, we asked the participating graduates of the department if they rely on the skills they acquired in the UOL courses in their daily lives. The results are shown in Figure 5. For both groups self motivation and time management are two comparatively valuable skills. For the graduates in industry, scheduling daily life is a more important skill that is gained during UOL courses compared to the graduates placed in academia. A significant difference in the answers between the graduates employed in industry and pursue academic career is observed in self confidence. This result may reflect that the graduates who continue their post-graduate studies find themselves in heterogeneous and scientifically competitive environment. A skill that is important for the graduates employed in industry arises as 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 is sufficient for the professional work environment. The graduates who continue to pursue advanced degrees might gain this skill through other graduate courses; hence this may not be an important skill for these students.

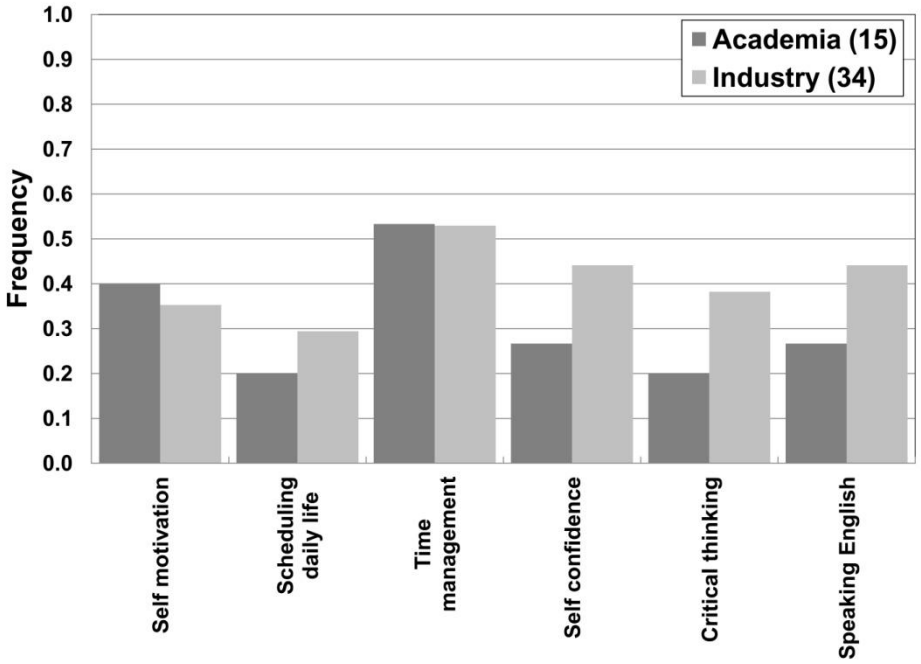


Figure 5: Skills used to regulate daily life

4. Conclusion

This paper summarizes the innovative design of the UOL course offered by the Chemical Engineering Department of a non-profit, private university in Turkey. The course design, in addition to preserving academic rigor of the UOL courses, supplements the students with additional skills which fulfill the demands of professional life. In addition, the results of a survey measuring whether or not the course outcomes are achieved in this regard are presented. This unique survey targeting the graduates of the department inquires which skills are valuable in professional careers and in managing the daily lives. The latter measurement is important for the life-long learning objective, one of the major requirements of the Bologna process. The survey results reveal graduates employed in the industry rely on these skills in job interviews, research and product development. The results also show that with the skills gained during the UOL courses, the graduates employed in industry are well equipped and well prepared for professional life. The answers of the graduates who attend post-graduate programs reveal that the skills they attained help during their research. Evaluating team members and public speaking are reported as valuable skills attained through the UOL courses. Furthermore, the results show that the participating graduates who pursue advanced degrees may use skills different than the skills used by graduates employed in industry, highlighting the need of an adaptive approach in meeting different professional careers of the students.

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