Int. J. Engng Ed. Vol. 23, No. 6, pp. 1219–1231, 2007
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Bridging the Gap Between Chemical Engineering Education and Industrial Practice*

SEYDA BUCAK,[1] ZOYA TUIEBAKHOVA,[1] NESET KADIRGAN[2]
[1] *Department of Chemical Engineering, Yeditepe University, Istanbul, Turkey.*
E-mail: seydabucaz@hotmail.com
[2] *Department of Chemical Engineering, Marmara University,Istanbul, Turkey*

Being a student is usually followed by working in industry and the transition from one to the other may be challenging. In our research, we conduct a lengthy survey and ask chemical engineers, who have graduated from university in the past 10 years, to evaluate the education they received in respect of expectations in industry. We received 200 replies and quantitatively analysed the results. With information from the survey, we turned our attention to our education system and the curriculum, suggesting some changes accordingly. Our goal with this work is to propose a system that prepares students for what they might encounter in industry. Also, we would like to suggest ways to give them better exposure to industrial applications, needs and most recent developments through industry-related coursework. As a result, our ultimate aim is to find ways to reconnect the tenuous ties between university and industry and to intensify the exchange between chemical and related (pharmaceutical, biotechnology, etc) industries, which, in the long run, will result in mutual benefit for both academia and students.

Keywords: Chemical engineering education; industry-university collaboration; curriculum change

INTRODUCTION

USUALLY, when collaborations between university and industry are considered, they refer to research collaborations or similar high-level knowledge exchange. One very important and overlooked factor is that industry is a continuation of university education and, for most graduates, the transition is not particularly smooth.

To help graduates in their professional lives, a new form of university-industry collaboration should be formed that will result in a better, more useful and relevant education for engineers. As the needs of industry and the world change, the education system should not lag behind, but quickly adapt itself. A fast change can be facilitated by working closely with industry and taking into consideration its needs and expectations from a graduate.

The chemical industry is one of the fastest growing industries in Turkey. As a result, there is a strong demand for chemical engineers. As industries are diversifying, the horizons of chemical engineers are broadening. But, are chemical engineering educators really fulfilling the needs of the vast number of skills required of chemical engineers?

To shed some light on this, a questionnaire was sent to practicing chemical engineers. Some of the conclusions are presented along with the questionnaire and some tables with results.

In Turkey, going to university is a privilege. After completing eight plus four years of school education, each person has to take a test prepared by the Ministry of Education. This is a multiple choice test and the student completes questions in a given amount of time in areas related to his/her future goals. For example, a student intending to study engineering will answer questions in maths, chemistry, physics, biology and Turkish. After receiving the results of this test, students apply at their desired departments in the university of their choice. Overall, only about 20% of the students who want to continue to higher education can actually go to university. Getting accepted into a chemical engineering programme is even more challenging. Out of this 20%, the top 30% gets a chance to continue in a chemical engineering programme. In other words, chemical engineering graduates are in the top 6% of all Turkish university candidates.

Chemical engineering education lasts four years and can be roughly divided into two parts: chemistry and engineering. These four years are not an easy job for the student or for the educator. Usually, the first two years focus more on chemistry and mathematics and the last two on engineering. At the end of four years, the student should be ready to start a job as a chemical engineer.

What else does the student need to be a useful chemical engineer? Competence in computing for one, preferably fluent English, familiarity with certain tricks of the trade such as regulations, safety, and above all to be confident, interested, ability in problem solving and social acceptability.

* Accepted 1 December 2006.

Is this too much to ask for? Are we aiming too high and hence likely to miss the target? Even if all this is put into the curriculum, how much of it is actually learned by the student? Even though these make great topics for further research, at this point we would like to narrow it down to some suggestions about what a Turkish student needs for a life in industry, and what we as educators need to do to make our chemical engineering education more up-to-date.

Further into this investigation, the benefit of opening more lines of communication between educators in the universities and professionals in industry became clearer.

METHODS

The questions were put to engineers from different universities. If the survey had been restricted to only one university the results would also reflect the performance of one lecturer, which was exactly what we were trying to avoid.

The Turkish general public perceives some universities as being better than others. They require a high score from the university entrance exam and therefore, it is supposed, 'attract better students'.

In this survey, although we initially separated the replies from high-score and low-score universities (we grouped universities under two main categories), we were pleasantly surprised by the similarity of results, which suggests that the replies reflect a general phenomenon rather than being university-specific. We make this clear by presenting results with a couple of examples from the two types of university. If significant differences exist in the results at any stage, we will point this out.

Group X in the survey included answers from engineers who graduated from universities requiring high entrance scores (in the first 2% of all those that take the exam). Group Y consists of answers from engineers who graduated from universities that require lower entrance scores (in the 2-6% of all those that take the exam). The number of answers from each group is 103 and 97 respectively.

This survey was sent to chemical engineers, mostly in electronic format, with an introduction. In order to prevent easy and cliché answers such as 'education is bad' or 'courses are useless', the introduction below was presented before the questionnaire (see Appendix 2):

> The purpose of this survey is to understand how much of the education given at the universities satisfies the needs of graduate students in their professional lives. The results of this survey will be announced to universities, media and those who took part in the survey. In other words, the survey will be useful. The reason why you are being asked about the university that you graduated from or you work at, is to avoid accumulation of data that weighs in the same direction. Please, when you are replying to the questions, do not consider your feelings for particular professors or your general judgements, but reply taking into consideration your work experiences. Our other request is this: When you are giving your answers, especially about your negative thoughts please think this "Would my high school be adequate in this field for me to do what I am doing right now?" or "I learned this at my workplace but would I have been able to learn this with my high school knowledge? Which part of my education helped me in learning?

We limited our survey to those doing industry-related jobs and also restricted our group to those that graduated within the last 10 years; thus, we are actually surveying people who have a clear memory of their education and the more recent education system.

We have not yet come across an extensive study of this kind, neither for chemical engineers, nor for any other engineering fields. So, we hope that this will bring a new approach to the preparation of curricula.

RESULTS

The results are evaluated under two main subgroups: general answers and evaluation of courses taken one by one. The first few questions were aimed at finding out more about the profile of graduates who completed the questionnaire. Questions and answers will not be presented in detail; only some general conclusions that are drawn are summarized.

Chemical engineers consciously choose their profession; one reason may be that chemical engineers are amongst the top six per cent of those who succeed in the university exam and are therefore likely to be more conscientious and well-informed. After graduation, when it comes to choosing a job, most have to take what they can find, instead of opting for a specific field within chemical engineering, which leads us to this conclusion: increasing the number of elective courses in the curriculum, or further branching, as suggested by some, is not meaningful as the field in which a graduate will work is determined, not necessarily by the courses they take or their specialization, but the opportunities they come across.

The goal of a good education should be to teach a high number of compulsory courses well. In our survey, we got replies mostly from those working in the public sector, which is a good representation of the general picture, even though several firms have been privatized in recent years. Our sample group works in different fields of industry, which signifies that the group is not biased in one direction.

Answers to general questions

Q 1 Having graduated from university, do you believe that the theoretical information you received as a chemical engineer is useful and sufficient for your career?

Table 1

	Results (%)
Useful and sufficient	20.7
Useful and quite sufficient	14.5
It lacks important elements but I still benefit from it	62.8
Not sufficient, I do not use it, does not add to my high school knowledge	2.0

In order to quantify these results, we have given a coefficient to each answer as shown in Table 2.

Table 2

Useful and sufficient	Useful	4	Sufficient	4
Useful and quite sufficient	Useful	4	Quite sufficient	3
It lacks important elements but I still benefit from it	Useful	4	Lacks important elements	2
Not sufficient. I do not use it. It does not add to my high school knowledge	Useless	0		

Only 2% suggested that the theoretical information they received is useless (Not sufficient, I do not use it, does not add to my high school knowledge).We can say that 96% found the theoretical part of their education useful.

If we look at 'sufficiency', we can do the following calculation as shown in Table 3.

Table 3

	Coefficient	Results (%)	% × coefficient
Sufficient.	4	20.7	82.8
Quite sufficient.	3	14.5	43.5
Lacks important elements	2	62.8	125.6
Total			251.9

Maximum sufficiency would give a total of 400. The sufficiency of theoretical education is found to be 2.5/4. Although far from being perfect, we can say that graduates seriously benefit from the chemical engineering education that they received.

Q 2 Do you believe the laboratory education you received at the university to be sufficient and useful?

Table 4

	Results (%)
Yes, I learned a lot in the laboratory	25.5
I learned quite a bit in the laboratory but it could have been better	51.0
We lacked laboratory experience	23.5

Again, in an attempt to quantify the results, some coefficients are assigned as shown in Table 5 below.

Table 5

	Coefficient	% × coefficient
Learned a lot in the laboratory	2	51.0
It could have been better	1	51.0
Lacking laboratory experience	0	0
Total		102.0

In general, satisfaction with laboratory education is a little lower than that with theoretical education. The overall sufficiency of laboratory experience is 1.0/2 as opposed to 1.25/2 for theoretical education, which is in alignment with the general education understanding and lack of facilities in Turkey.

Q 3 For a better start in industry, what kind of a laboratory education do you suggest?

Table 6

	Results (%)
Smaller number of experiments with more theory	0.8
Higher number of experiments with less theory	16.0
A relevance between laboratory equipment and industrial applications	47.0
More information on different types and applications of common equipment	30.9

As we had suspected in advance that graduates find laboratory education lacking in certain elements, we included the above question in the survey. From the answers there is one conclusion that can be easily drawn: Chemical engineers expect laboratory practice which relates experiments to their significance in industry. We can also say that they also want to have more hands-on experience with different types of equipment.

Q 4 As a chemical engineer, what do you think should have been part of your education that would then have been useful in your work, (which area do you think you lack knowledge in)?

Table 7

	Results (%)
Quality systems	27.7
Work safety, worker health, environment and people safety	18.5
Computer	13.8
Foreign language	13.6
Regulations	11.7
More chemistry knowledge	7.4
Polymer	6.8

Generally, graduates lack knowledge about regulations and management. Lack of computer education and a foreign language is fast becoming a problem of the past. Today, most universities put a strong emphasis on foreign language learning, and computers are becoming such an integral part of our lives that when students graduate from universities they are already very proficient in computational skills.

Q 5 How long after you started working as a chemical engineer, did you start feeling confident?

Table 8

	Results (%)
Right away	24.5
6 months later	29.0
7–12 months later	20.5
More than 12 months	24.5

In terms of feeling confident, all answers are equally distributed, which means this may be more dependent on personality than the education received.

Q 6 Do you refer back to your university books or lecture notes?

Table 9

	Results (%)
Yes	14.8
Sometimes	48.5
No	37.0

It is difficult to interpret these answers.

Referring back to university books and notes suggests that the information given at the university is useful during professional life. On the other hand, not referring back may suggest the following:

1. The graduate knows them already.
2. The information is not there.
3. The information needed is more complex than what has been thought at the university.
4. The graduate cannot connect the problem with what was learned at the university.

Although some may refer back to their university books and notes it is not obvious exactly why they do so, while for those that do not refer back it is not obvious exactly why do not.

Q 7 In the course of your education how well do you think you were instructed on the following subjects (Table 10)?

To evaluate the results in a more meaningful way, we give the following coefficients to answers and normalize according to the following equation as shown in Table 11.

$$[(\text{Column I} \times 2) + (\text{Column II} \times 1) + (\text{Column III} \times -1) + (\text{Column IV} \times -2)]/100.$$

Table 11

More than enough	2
Sufficiently	1
Not very sufficiently	−1
Insufficiently	−2

Table 12

Between 1 and 2	More than enough
Between 0 and 1	Close to sufficient
Between −1 and 0	Insufficient
Between −2 and −1	Completely insufficient

According to this, for chemical engineers, theoretical and mathematical knowledge is taught more than sufficiently. Laboratory practice is closer to insufficient, which is consistent with previous answers. Personal and written presentation skills are borderline between being insufficient and close to sufficient.

The most insufficient is laws and regulations. This opinion is passed repeatedly throughout the survey. As we mentioned earlier, computational skills are fast improving and language skills are also becoming less of a problem.

Q 8 What did you gain from the summer internships that you did during university?

Table 13

	Results (%)
Nothing	4.5
I obtained more knowledge about the chemical industry	20.0
They helped me get a job	6.5
I had the opportunity to find out about different industries	25.5
My expectations became more realistic	12.0
I learned to work with different people	14.5
I found out more about what kind of work interests me	15.5

Table 10

Subjects	More than enough (%)	Sufficiently (%)	Not very sufficiently (%)	Insufficiently (%)
Theoretical knowledge	50.5	43.2	5.26	1.05
Practical knowledge	2.11	23.2	48.4	26.3
Laboratory skills	6.32	46.3	34.7	12.6
Personal skills	8.42	30.5	42.1	18.9
Written presentation skills	15.8	23.2	34.7	26.3
Oral presentation skills	7.4	19.0	41.0	32.0
Mathematics	32.6	60.0	5.3	1.1
Laws and regulations	0.0	4.2	26.0	69.0
Computer	9.47	16.8	27.4	46.3
Foreign language skills	6.32	24.2	18.9	49.5

If we look at the results from high- and low-ranking universities as described in the introduction, we get very similar results as shown in Table 14.

Table 14

	Group X (%)	Group Y (%)
Nothing	4	5
I obtained more knowledge about the chemical industry	17	23
They helped me get a job	9	4
I had the opportunity to find out about different industries	26	25
My expectations became more realistic	13	11
I learned to work with different people	14	15
I found out more about what kind of work interests me	15	16

As those who answered 'nothing' to this question are very few, we can conclude that summer internships are useful and maybe should even be extended. Currently, most universities have compulsory internships in their curriculum. Although some universities accept internships that are carried out in university laboratories instead of industry, these results suggest that students benefit from contact with the industry. The top five answers are all related to benefits from getting in touch with industry. As this is considered a part of education, all institutions directly or indirectly related to chemical engineering should accept their role in this and continue providing this educational component to their students.

Q 9 What did you gain from your university graduation project?

Table 15

	Results (%)
Nothing	11.5
I made calculations on how to design a factory	16.0
I learned how to gather information and present it to managers	24.0
I learned a lot about a special topic	21.0
I learned to write scientifically which then helped me write technical reports	18.5
I made some experiments and collected meaningful data which then helped me carry on research projects	9.5

The graduation project is a type of course that the student carries out on an individual basis. It is obviously beneficial.

Q 10 What percentage of the knowledge gained from your education (or skills that you built on it) are you using?

Table 16

	Results (%)
100%	1.5
75–99%	12.5
50–74%	40.0
25–49%	39.5
Less than 25%	17.0

To combine the results, if we give a coefficient to each answer as shown in Table 17.

Table 17

	Coefficient
100%	4
75–99%	3.5
50–74%	2.5
25–49%	1.5
Less than 25%	0.5

and then take the weighed average, we see that for both groups approximately 50% of the information given is actually used. If we consider that graduates end up working in very different fields throughout their professional lives, we can conclude that their using 50% of the knowledge gained at the university is a very good result.

Q 11 Evaluation of courses

The answers to this question are given in Appendix 1.

This question sets out to evaluate a total of 35 compulsory and elective courses that are in the curricula of chemical engineering departments. This is probably the most important question of the survey where graduates have a chance to express their opinions on university subjects after they have started working in industry.

The courses were put into four different categories:

1. Physics, Maths and Computer (Science) group
2. Chemistry group
3 Management group
4. Engineering group.

Because some of these 35 courses were electives and therefore not taken by some engineers, it was found more appropriate to give them different weightings.

Table 18

% Students that took the course	Weight coefficient
>80%	6
60–80%	4
40–60%	2
<40%	1
Number of semesters for the course	
1 semester	1
2 semesters	2
3 semesters	3

Table 19

Answer	Implication	Coefficient
Partially useful	Positive evaluation	1
Useful	More positive evaluation	2
There should have been even more of this content	Very positive evaluation	3
Could do with less content	Strong negative	−3
Not necessary	Very strongly negative	−5

In order to reach some quantitative results, the answers were evaluated in three different ways:

1. *Useful-Necessary Coefficient*

The possible answers for the graduates are shown in Table 19.

The Useful-Necessary coefficient was then defined as:

Useful-Necessary Coefficient = [1(Partially Useful) + 2 (Useful) + 3 (Should have had more content) −3 (Could do with less content) −5 (Not necessary) / 100

2. *Benefit Coefficient*

In order to focus on how beneficial the course was, the benefit coefficient was coined using the same coefficients as above:

Benefit Coefficient = [1(Partially Useful) + 2(Useful)] * 1.5/100

3. *More Demand Coefficient*

This coefficient is an indication of a demand for more, which implies a need that is felt today and was not fulfilled during the education.

More Demand Coefficient = [2 (Should have had more substance) −1 (Could do with less substance)—(Not necessary)]/100

These three coefficients can be used to compare the courses with one another, although the coefficients themselves cannot be so compared.

An important note on the coefficients is that they are completely arbitrary; even if different coefficients are assigned, only the numeric value changes, the conclusions that can be drawn are essentially the same. The results are summarized in Table 20.

The summary of weighed averages of groups can be seen in Table 21.

The conclusions that can be drawn from this data analysis are as follows:

Chemical engineers, in their professional lives, benefit most from courses in the physics-math-computer group, followed by chemistry courses, engineering courses and then management courses. On the other hand, management courses are by far the most in 'more demand'. Management courses are followed by chemistry courses. Science and engineering courses can be regarded as sufficient; there seems to be not much need for more.

If we look at the groups individually:

1. Physics-Mathematics-Computer group: These topics are very useful in graduates' professional lives but they find the education sufficient; there is no need for more. However, a more detailed investigation brings out the fact that FORTRAN computer language is viewed as useless, whereas there seems to be a demand for more computer and mathematical techniques
2. Chemistry group: The graduates not only find the existing courses useful but there is also a demand for more.
3. Engineering group: The graduates find the existing courses useful and there is a demand for more—which is less than the demand for the chemistry group.
4. Management group: Although not as highly rated as chemistry, courses in the management group are found to be useful, but the survey clearly reveals that students need to be more educated in this kind of knowledge in their professional lives.
5. Usually, as these courses are provided to chemical engineering departments by other departments, they are viewed as service courses, which may lower the quality. Also, students being buried under the weight of their engineering courses are likely to view these courses as 'not important' and 'easy' and therefore not realize their importance subsequently.

CONCLUSIONS

This survey was aimed at the assessment of chemical engineering education by graduates themselves who have started their professional lives. The consistency of results shows that the questions were very seriously answered. The main general conclusions that can be drawn from this questionnaire are as follows:

Chemical engineers use more than half of the theoretical and practical knowledge given to them during university education in their professional lives. This is contrary to the common belief that 'the education is useless'.

There is no significant difference between chemical engineers in terms of finding a job, what the job is, how much their university formation is beneficial, etc. In other words, the situations they encounter are not university-specific; the problems, opportunities, difficulties are somewhat the same for all chemical engineering students.

Chemical engineers in their professional lives feel the need for:

1. Management-related topics;
2. Computer and foreign language information;
3. Chemistry-related topics.

Table 20

Courses	Weight coefficient	Useful-necessary coefficient	Benefit coefficient	More demand coefficient
Science group				
Maths-related	18	1.48	1.01	0.02
Physics	12	−0.06	0.58	−0.28
Fortran	2	−2.20	0.30	−0.99
Computer	6	1.95	0.52	0.85
Statistics	4	1.36	0.49	0.58
Mathematical techniques	4	1.55	0.76	0.36
Weighed average		0.93	0.74	0.075
Chemistry group				
General chemistry	12	1.66	0.94	0.22
Analytical chemistry	6	0.65	0.57	0.27
Organic chemistry	6	1.37	0.71	0.33
Physical chemistry	6	1.13	0.73	0.16
Electrochemistry	4	0.67	0.59	0.09
Bioorganic chemistry	1	−0.52	0.27	−0.14
Corrosion	2	0.61	0.60	0.10
Textile chemistry	1	0.21	0.39	0.59
Pharmaceutical chemistry	1	1.13	0.42	0.85
Polymer	2	1.57	0.57	0.58
Weighed average		1.25	0.71	0.25
Management group				
Management	4	1.88	0.52	0.80
Engineering economics	4	1.91	0.62	0.70
Work safety and health	2	1.96	0.51	0.87
Law for engineers	2	1.64	0.37	0.58
Weighed average		1.78	0.52	0.74
Engineering group				
Separation processes	6	1.16	0.77	0.12
Introduction to chemical engineering	6	1.65	0.79	0.37
Thermodynamics	6	1.10	0.81	0.09
Heat transfer	6	1.22	0.83	0.08
Mass transfer	6	1.24	0.83	0.11
Fluid mechanics	6	0.91	0.74	0.04
Reactor design	6	0.87	0.64	0.13
Process dynamics and control	6	1.25	0.69	0.29
Process design	6	0.67	0.66	0.28
System analysis and modelling	6	0.57	0.65	0.02
Materials	6	0.20	0.49	0.07
Mechanics	2	1.08	0.45	0.45
Statics	4	−0.09	0.50	−0.20
Dynamic	4	0.03	0.57	−0.18
Energy-related	6	1.37	0.53	0.51
Weighed average		0.95	0.68	0.14

Table 21 Summary of weighted averages of groups

	Useful-necessary coefficient	Benefit coefficient	More demand coefficient
Science	0.93	0.74	0.075
Chemistry	1.25	0.71	0.25
Engineering	0.95	0.68	0.14
Management	1.78	0.52	0.74

As management-related topics appear to be the most needed ones in professional life, these courses should be taken very seriously, with more emphasis given to them, ensuring courses are given by proficient lecturers.

A very striking result is the fact that chemical engineering graduates use and need chemistry courses more than engineering courses. The main reason for this is the discrepancy between the chemical engineering education and the places where chemical engineers end up working. In other words, fields universally considered as areas for chemical engineers are left to other professions in Turkey.

After this important observation, it is obvious that chemical engineering academics should contribute to the resolution of this problem, either by giving more chemistry in a more efficient way, or by taking an active role in expanding the professional areas for chemical engineers.

For graduates to use their specialist information in a way that is most beneficial to society, academic staff should take more responsibility. Progress in this area can only be achieved by the contribution of all chemical engineers.

Somewhat unexpectedly, the survey shows that internships are very beneficial. Most of the responsibility in this important part of chemical engineering education lies not specially with academics, but with all institutes, firms and organizations related to chemical engineering. All chemical engineers should generously contribute to this for their young colleagues.

We believe there is not one recipe or one solution for education. Each country and each field should take into account past and parallel experiences of others, yet deeply consider its own situation, jobs, market and position globally. In some cases, specialized institutions may be able to define themselves with a certain type of education that is tailored towards a specific need by industry. Instead of adapting a generic programme, we suggest that each institute, regardless of location, should think about its potential for 'value-added' and design a curriculum accordingly. This way we believe would be most beneficial for students when they leave the education system and try to find a place for themselves in the working world.

Acknowledgements—We would like to thank Chamber of Chemical Engineering, Istanbul Branch for their technical and logistical support. We would like also to acknowledge George Zitros for English editing.

Seyda Bucak is an Assistant Professor in the Department of Chemical Engineering at Yeditepe University, Turkey. She received her BSc in Chemistry from Bogazici University, Turkey and her Ph.D. in Chemistry from University of East Anglia, UK. Her research is mainly on surfactant science with concentration on nanoparticles, nanostructures and applications. She also carries out active research in engineering education.

Zoya Tuiebakhova is an Associate Professor in the Department of Chemical Engineering at Yeditepe University, Istanbul, Turkey. She received her BSc, MSc, and Ph.D. in Chemistry from Moscow Mendeleev Chemical Technological University. Her research is on Coordination Chemistry, Computational Chemistry and in Engineering Education.

Neset Kadirgan is a Professor in the Department of Chemical Engineering at Marmara University, Turkey. He has BSc and Ph.D. (Doctorat d'Etat) degrees from Poitiers University, France. He is head of The Chamber of Chemical Engineers (CCE) Istanbul branch. His research areas are combustion, heat transfer and safety in chemical engineering. He is also strongly interested in engineering education for administrative and academic purposes.

APPENDIX 1

Evaluation of courses taken during chemical engineering education

Courses	Useful		Partially useful		Should have had more content		Could do with less content		Not necessary		Never ran into it	
	X%	Y%	X%	Y%	X%	Y%	X%	Y%	X%	Y%	X%	Y%
Maths-related	58	68	34	15	3	5	4	11	0	1	0	0
FORTRAN	11	10	26	20	6	8	4	13	54	50	39	56
Separation processes	28	50	46	30	13	13	9	6	5	1	6	7
Introduction to chemical engineering	46	47	28	24	20	24	6	4	1	1	2	7
Computer	38	31	11	9	45	47	5	2	2	1	2	15
Physics	21	31	39	33	4	8	26	22	10	6	2	1
General chemistry	49	66	33	18	12	16	6	5	0	0	0	0
Analytical chemistry	38	58	31	18	16	20	11	3	1	1	3	2
Organic chemistry	33	49	31	18	25	21	11	8	1	3	0	1
Physical chemistry	24	52	42	26	17	14	16	6	2	2	1	0
Electrochemistry	11	41	47	24	17	19	17	11	8	5	26	20
Thermodynamics	40	52	32	29	9	12	19	7	1	1	1	2
Heat transfer	43	50	37	29	9	11	11	10	0	1	1	3
Mass transfer	40	52	38	27	10	12	10	7	1	2	1	5
Fluid mechanics	36	45	31	29	14	10	15	14	3	2	1	2
Reactor design	30	38	33	25	16	21	16	11	4	6	1	10
Process dynamics and control	39	35	30	27	17	26	11	10	3	1	2	8
Unit operations	35	37	30	22	19	27	13	12	4	1	9	26
System, analysis and modeling	34	34	28	30	14	26	16	9	16	9	8	19
Bioorganic	9	4	31	25	16	33	25	13	19	25	63	72
Materials	21	22	31	28	24	2	18	17	6	10	4	8
Numeric analysis	40	51	24	23	27	20	5	3	3	4	21	22
Corrosion	28	41	30	13	25	23	13	13	5	20	54	55
Textile chemistry	13	29	0	33	47	38	27	0	13	0	83	76
Pharmaceuticals	25	19	13	25	54	44	8	6	0	6	74	82
Polymers	23	42	23	20	43	30	7	2	4	6	35	46
Business administration	28	27	20	25	47	41	4	5	1	2	23	51
Engineering economics	26	42	25	25	44	30	4	3	1	0	23	22
Work safety and worker health	23	34	17	21	55	39	2	5	2	2	49	56
Business law	10	18	29	27	51	32	7	9	3	14	36	55
Mechanics	13	22	37	28	39	28	9	14	2	8	48	46
Statics	17	22	36	36	12	14	21	13	13	16	13	28
Dynamics	16	25	40	38	11	12	23	15	10	12	19	23
Statistics	23	29	26	16	39	39	8	10	5	6	31	44
Courses related to energy	14	33	35	30	39	26	8	10	4	1	19	18

APPENDIX 2

Survey questions

Name, Surname ______________________________

1. Which university did you graduate from and which year? ______________________________

2. How did you decide to study chemical engineering?
   (a) I liked maths and sciences in high school.
   (b) I was especially interested in chemistry.
   (c) My family wanted this for me.
   (d) I wanted to be an engineer, but my exam results were sufficient for chemical engineering.
   (e) An advisor/mentor directed me.
   (f) Other (Please specify): ______________________________

3. How did you decide which field to work in after university?
   (a) I found a job in this field.
   (b) I had an interest in this field when I was studying.
   (c) My family wanted this for me.
   (d) I decided during my summer internships.
   (e) I thought this sector would have good opportunities for growth.
   (f) Other (Please specify): ______________________________

4. What kind of establishment do you currently work for?
   (a) Public.
   (b) Private, part of a holding.
   (c) Private, small single-owner business.
   (d) Consulting.
   (e) Other (Please specify): ______________________________

5. Which industry area are you working in?
   (a) Quality control and process engineering
   (b) Production
   (c) Product management
   (d) Research and development
   (e) Sales
   (f) Marketing
   (g) Finance
   (h) Environment or quality management
   (i) Responsible manager
   (j) Other (Please specify): ______________________________

6. Which field are you working in?
   (a) Paint, vanish and adhesives.
   (b) Textile treatment.
   (c) Earth industry.
   (d) Glass.
   (e) Inorganic chemicals.
   (f) Organic chemicals.
   (g) Pharmaceuticals.
   (h) Food.
   (i) Metal industry.
   (j) Project, contracting company.
   (k) Quality, fire and work safety consulting.
   (l) Chemical materials and equipment sales.
   (m) Energy (oil refinery, central power station, solar energy, etc)
   (n) Plastic goods production.
   (o) Distillation, waste water treatment.
   (p) Other (Please specify): ______________________________

7. What is your job title? ______________________________

8. Please give your opinion on the following subjects taught at the university (You can mark more than one depending on its use and content.).

Courses	Useful	Partially useful	Should have had more substance	Could do with less substance	Not necessary	Never ran into it
Maths-related						
Fortran						
Separation processes						
Introduction to chemical engineering						
Computer						
Physics						
General chemistry						
Analytical chemistry						
Organic chemistry						
Physical chemistry						
Electrochemistry						
Thermodynamics						
Heat transfer						
Mass transfer						
Fluid mechanics						
Reactor design						
Process dynamics and control						
Unit operations						
System, analysis and modeling						
Bioorganic						
Materials						
Numeric analysis						
Corrosion						
Textile chemistry						
Pharmaceuticals						
Polymers						
Business administration						
Engineering economics						
Work safety and worker health						
Business law						
Mechanics						
Statics						
Dynamics						
Statistics						
Courses related to energy						

9. Having graduated from university, do you believe that the theoretical information you received as a chemical engineer is useful and sufficient for your career?
   (a) Useful and sufficient.
   (b) Useful and quite sufficient.
   (c) It lacks important elements but I still benefit from it.
   (d) Not sufficient, I do not use it, does not add to my high school knowledge.

10. Do you believe the laboratory education at the university to be sufficient and useful?
   (a) Yes, I learned a lot in the laboratory.
   (b) I learned quite a bit in the laboratory but it could have been better.
   (c) We are lacking in laboratory experience.

11. For a better start in the industry, what kind of a laboratory education do you suggest?
   (a) Smaller number of experiments with more theory.
   (b) More experiments with less theory.
   (c) A relevance between laboratory equipment and industrial applications.
   (d) More information on different types and applications of common equipment.
   (e) Other (please specify): ______________________________

12. As a chemical engineer, what do you think should have been a part of your education that would then have been useful in your work life, (which area do you think you lack knowledge in)?
   (a) Regulations.
   (b) Quality systems.
   (c) Work safety, worker health, environment and people safety.
   (d) Foreign language.
   (e) Computer.
   (f) More chemistry knowledge.
   (g) Polymer
   (h) Other (please specify): ______________________________

13. After you started working as a chemical engineer, how long before you started to feel confident?
   (a) Right away.
   (b) 6 months later.
   (c) 7-12 months later.
   (d) More than 12 months.

14. Do you refer back to your university books or lecture notes?
   (a) Yes.
   (b) Sometimes.
   (c) No.

15. In the course of your education how well do you think you were instructed on the following subjects?

Subjects	More than enough	Sufficiently	Not very sufficiently	Insufficiently
Theoretical knowledge				
Practical knowledge				
Laboratory skills				
Personal skills				
Written presentation skills				
Oral presentation skills				
Mathematics				
Laws and regulations				
Computer				
Foreign language skills				

16. What did you gain from the summer internships that you did during university?
   (a) Nothing.
   (b) I obtained more knowledge about the chemical industry.
   (c) They helped me get a job.
   (d) I had the opportunity to find out about different industries.
   (e) My expectations became more realistic.
   (f) I learned to work with different people.
   (g) I found out more about what kind of work interests me.
   (h) Other (please specify): ______________________________

17. What did you gain from your university graduation project?
    (a) Nothing.
    (b) I made calculations on how to design a factory.
    (c) I learned how to gather information and present it to managers.
    (d) I learned a lot about a special topic.
    (e) I learned how to write scientific writings which then helped me write technical reports.
    (f) I made some experiments and collected meaningful data which then helped me carry on research projects.
    (g) Other (please specify): ______________________________

18. What percentage of the knowledge gained from your education (or skills that you built on it) are you using?
    (a) 100 %
    (b) 75–99 %
    (c) 50–74 %
    (d) 25–49 %
    (e) less than 25%